A TEST FOR MEASURING THE PHYSICAL CAPACITY OF SECONDARY SCHOOL BOYS

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PUBLISHED WITH THE APPROVAL OF
PROFESSOR J. F. WILLIAMS, SPONSOR

SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF DOCTOR OF
PHILOSOPHY IN THE FACULTY OF PHILOSOPHY,
COLUMBIA UNIVERSITY

NEW YORK, N.Y.

1933

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ACKNOWLEDGMENTS

The author wishes to express his appreciation of the wholehearted coöperation of the boys of the Gorton High School and the Saunders Trade School, Yonkers, N.Y., in submitting to a tedious testing program. More specifically, he wishes to acknowledge the sincere help of Joseph McConnell and Dorothy Perkins for their expert services in tabulating the results; to Mr. George Foster and to Mr. Edward Hofmann for their very able assistance in the administration of the tests; to the members of his dissertation committee, Professor J. F. Williams, sponsor, Professor W. A. McCall and Professor C. L. Brownell for their kindly advice and criticisms; to the Misses Loretta Prendergast and Dorothy Souers for their untiring efforts in the preparation of the manuscript, to John Clarkson for his valuable help on the plates. The most respectful appreciation is felt for the studies of Dr. F. W. Cozens, Dr. R. Franzen, Dr. D. K. Brace, Dr. F. R. Rogers, Dr. D. A. Sargent and Dr. C. H. McCloy from which the author gained many helpful suggestions and inspirations. And finally the author wishes gratefully to acknowledge the ever constant sympathy and inspiration of his mother, without whose help and sacrifice this work would have been impossible.

H. L. M.

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CHAPTER I

INTRODUCTION

Purpose of the Study. The purpose of this study is to construct a test that will be a valid and reliable measure of the physical capacity of the large muscle groups which may be used to classify pupils into homogeneous groups for physical education activities. It may be well at the beginning to define the terminology used in this study. Because of the lack of clarity, different writers have used various terms in referring to physical capacity. It is understood that herein physical capacity is interpreted to mean the capacity of the large muscle groups to translate power. Athletic achievement is used in the sense of accomplishment, that is, the accomplishment of the individual in being chosen one of a highly selected group representing an athletic team. Athletic performance is the term applied to the actual performance of a specific athletic skill, or battery of skills, as running, jumping, etc. This study is concerned only with the capacity required in the performance of the act. In other words as Alden, Horton and Caldwell[1] state, "An individual may have the capacity to do a thing and not the skill to do it." However, it must be borne in mind that those who have attained a high proficiency in athletic team games must have the physical capacity to perform these muscular acts. Physical capacity is conditioned in the main by two factors, that of muscular force inherent in the muscle fiber and that of muscular velocity inherent in the innervation of the muscle cells. Ideally, these two factors should so combine in the expression of physical power that the result is efficient movement with the least expenditure of energy. This is what Williams[2] calls the Energy Activity Ratio. An individual may have a high degree of muscular force or strength without the ability to translate this force into movements that require a high degree of speed, and on the other hand, an individual may be able to express a high degree of muscular

[1] Alden, Florence D., Horton, Margery O'Neil and Caldwell, Grace Marie, A Motor Ability Test for University Women for the Classification of Entering Students into Homogeneous Units, p. 87.

[2] Williams, J. F. Principles of Physical Education, p. 325.

velocity without having sufficient development of muscle tissue for this velocity to act upon in expressing power of movement. A muscle-bound strong man would be an illustration of the first condition. He might possess the kind of power necessary to lift two hundred pounds over his head but would probably take fifteen seconds to run a hundred yards. The muscular velocity expressed by a hundred pound typist would illustrate the second condition.

Schmidt[3] points out that "There are two kinds of muscular work, first, the work of short duration calling for the maximum expression of force (strength), and second, the kind of work that is distributed over a number of large muscles, calling for only a fraction of the maximum force of each muscle." If the latter is of short duration and calls for a large amount of work, as in the hundred yard dash, we refer to it as an exercise of speed.

No attempt was made in this study to investigate extensively the physiology of muscular phenomena aside from the general principles involved. However, we were interested in the practical application of the Physical Capacity Index as a means of indicating the muscular needs of the individual. Tyler[4] proposes that, "The muscular system . . . is the strategic center, from and through which we can reach, exercise, and strengthen all the organs of the will. . . ." The proper administration of the Physical Capacity Test presupposes a thorough health examination. The assumptions and findings of this study were based on individuals of healthy, normal faculties.

In summarizing the general plan of attacking the problem, the procedure was as follows:

1. The hypothesis that muscle strength alone was insufficient in the measurement of physical capacity was investigated.

2. In collecting the data, the tests and measurements described in Chapter II were used as tools for analyzing the following:

(a) How does structure influence athletic performance of various kinds? How does it influence physical capacity?

(b) What kinds of measures differentiate the trained athlete from the untrained individual, and to what degree?

(c) What kind of muscular forces are more potent in the vigorous big-muscle, athletic activities?

(d) How important is muscular velocity in the performance of vigorous big-muscle activities?

[3] Schmidt, F. A. Physiology of Exercise, pp. 95-96.
[4] Tyler, J. M. Growth and Education, p. 41.

(e) What is the best way of measuring muscular force in order to obtain a muscular force index?

(f) What is the best method of measuring the muscular velocity of the big-muscle groups?

(g) Accepting the engineers' measure of capacity as power, what is the best way of measuring physical power in the muscular sense?

(h) Will the mechanical principle that capacity measured in power units, equals force times velocity, hold for physical capacity?

3. The Physical Capacity Index as developed in Chapter V is presented as a measuring tool which combines the two fundamental factors of power, namely, force and velocity. The final index that best measured the kind of muscular capacity we find in athletes, was the product of the Muscular Force Index (described in Chapter III) and the Muscular Velocity Index (described in Chapter IV).

(4) The use of the Physical Capacity Index in classifying students in physical education programs will necessarily be dependent upon the kind of program, its aim and objectives. The Physical Capacity Index is basic from the standpoint of muscular power and it is not intended that it will supplant other forms of classification tests. The following key is presented to enable the reader to know at a glance the composition of the various tests and indices referred to in this study.

KEY

STRENGTH INDEX (ROGERS) = 1/10 Weight + (Height — 60) multiplied by the total number of Arm Pullups and Pushups plus the sum of Lung Capacity (cu. in.), Back Strength, Leg Strength, Rt. Grip Strength and Lt. Grip Strength. (Score in total points.)

FORCE INDEX = Arm Pulling Force + Arm Pushing Force + Back Force + Leg Force + Grip Force (sum of Lt. and Rt.). (Score in total pounds, tests weighted equally.)

VELOCITY INDEX = The Vertical distance jumped by a subject. (Score in inches.)

ATHLETIC PERFORMANCE INDICES (1928 Battery) = Ten second run + Running high jump + Running broad jump + Eight pound shotput. (Score was computed by taking the sum of the T scores in each of the four events with the Run score taken twice.)

1929 Battery = Hundred yard dash + Running high Jump + Standing broad jump + Eight pound shotput. (Index No. 1 was

the sum of the T scores in the four events and Index No. 2 was computed from the McCloy Tables as the sum of the points achieved in the four events.)

1931 Battery (Modified Cozens' Athletic Performance Index) = Ten second run + Standing broad jump + Eight pound shotput + Dodge run + Arm pushups + Football punt for distance + Baseball throw for distance. (Score was the sum of the T scores weighted as follows: Running 1.2; Jumping 1.0; Shotput 1.0; Dodging 1.0; Arm pushups 0.6; Punting 1.0; Throwing 1.5.)

ATHLETIC ACHIEVEMENT = High honor award in one or more inter-scholastic athletic sports. ("Making" the Varsity Letter.)

BASKETBALL INDEX = Average rating by eight judges on the basis of one to twenty (one is low and twenty is high) of basketball playing ability.

MOTOR ABILITY INDEX (Brace) = The number of motor stunts successfully passed out of a total of twenty. (Score in T-scale units.)

McCLOY CLASSIFICATION INDEX = Twenty times the age, plus six times the height, plus the weight. (Score in points.)

ENERGY INDEX = Weight times Vertical Jump. (Score was the number of inch pounds of work done.)

PHYSICAL CAPACITY INDEX NO. 1 = Force Index multiplied by the Velocity Index and the product divided by one hundred.

PHYSICAL CAPACITY INDEX NO. 2 = (Strength Index) + (177 times Velocity Index).

PHYSICAL CAPACITY INDEX NO. 3 = Strength Index multiplied by the Velocity Index and the product divided by one hundred.

CHAPTER II

SOURCES OF DATA AND METHODS OF MEASUREMENT

Experimental Groups

One thousand four hundred and fourteen cases were used in this study comprising the boys (those not excused by a physician's certificate) in the physical education programs of the Gorton High School and the Saunders Trade School, Yonkers, N.Y. The groups studied included only American-born white boys, ages distributed as follows: seventy-two 13 year olds, two hundred and fifty-nine 14 year olds, three hundred and fifty-nine 15 year olds, three hundred and eighty-three 16 year olds, two hundred and six 17 year olds, one hundred and ten 18 year olds, twenty-two 19 year olds and three 20 year olds.

Testing Methods

The collecting of data used in this study began in the Spring of 1928 and was carried along with certain modifications through the years 1929, 1930 and 1931. The investigator was aided in applying the various tests and measurements by trained student and faculty assistants. At the subsequent description of the tests will show, the reliability of each test was established in most cases by two or more applications of the test with carefully controlled conditions as to time, temperature, wind, rechecking of the measuring instruments, physical condition of subjects, etc.

Description of Tests

The general conditions governing the administration of all the tests were as follows:

(a) The tests were given during the regular scheduled physical education class periods. The periods were fifty minutes in length and occurred twice weekly.

(b) All subjects were dressed in the conventional gymnasium costume consisting of light rubber soled shoes, short cotton trunks and sleeveless cotton shirts.

(c) Each physical test was preceded by the following general instructions:

1. Do not take this test unless you feel sure you can do your best. Those who have had major operations, serious illnesses or broken bones in the past six months are excused.

2. It is important that you feel physically fit. If for any reason you do not feel that you can do your best because of a sore hand or foot, a cold, upset stomach or for any other reason, you will be excused and tested later.

Measurements of Structure

1. *Age*—recorded in years and months and checked from the school registration cards.

2. *Weight*—recorded in pounds and in kilos to the nearest pound and nearest tenth of a kilo. The subject was in stocking feet and light underwear or its equivalent.

3. *Height*—recorded in inches and in centimeters to the nearest quarter inch and nearest centimeter. The subject stood erect on scale platform in his stocking feet.

4. *Shoulder breadth*—recorded in centimeters to the nearest tenth of a centimeter with the jaws of the breadth calipers held at an angle of forty-five degrees, tips in firm contact with the outer surfaces of the acromion processes of the scapulae, subject sitting erect on a stool and the measurement taken by examiner standing in the rear of the subject.

5. *Chest breadth*—recorded to the nearest tenth of a centimeter while the jaws of the breadth calipers were held horizontal to the floor, inner surfaces of jaws in firm contact with the outer surfaces of sixth rib (about five centimeters below the arm pits). The subject was told to take a moderate breath and let it all out. The reading was taken at expiration from in front of standing subject.

6. *Hip breadth*—recorded to the nearest tenth of a centimeter while the jaws of the breadth calipers were held firmly in contact with the outermost points of the iliacs so that caliper jaws slope down at an angle of forty-five degrees; examiner standing in front of subject.

7. *Chest depth*—recorded to the nearest tenth of a centimeter while the examiner stands on the left of the subject holding the anterior knob of the caliper jaw to a point on the center line of the sternum horizontally in line with the articulating point of the third rib with the sternum. The posterior knob of caliper jaw was held in

contact with a spinous process such that the calipers remained parallel with the floor. The measurement was taken at expiration.

In developing the Velocity Index (see Chapter IV) the following additional measures of structure were necessary:

8. *Sitting height*—taken as the sitting height to the top of head while subject sat on stall bar stool. Recorded to the nearest centimeter.

9. *Thigh length*—taken with subject in sitting position on stall bar stool in such a manner that the thigh remained parallel with the floor. The measurement was recorded to the nearest centimeter while the anterior jaw of the caliper was held in firm contact with the front surface of knee and the posterior jaw held in firm contact with the buttocks.

10. *Leg length*—taken with subject in sitting position on stall bar stool so that the lower leg and thigh were at a right angle with each other. The measurement was recorded to the nearest centimeter while the lower jaw was in a position under the heel and the upper jaw was in a position on the top of the knee.

11. *Arm reach*—taken as the distance from middle finger tip to middle finger tip while the subject stood with back against wall scale with arms sideward stretched. The measurement was recorded to the nearest centimeter.

Tests of Function

1. *Strength*—the strength of the big-muscle groups as used throughout this study was measured by the Rogers[1] Strength Test (see key p. 3) with certain modified techniques as described below.

2. *Muscular force* (see Plates, pp. 49-54)—In order to obtain a clear cut measure of force that could be recorded in pounds of force, the Rogers Strength Test was modified and the following Force Index was developed:

(a) *Grip force*—recorded as the sum of the pounds of force achieved with the right and left hands on the hand dynamometer. Rogers[2] testing technique was followed.

(b) *Leg force*—recorded in pounds of force as measured by the Rogers[3] technique with the leg and back dynamometer.

(c) *Back force*—recorded in pounds of force as measured by the Rogers[4] technique with the leg and back dynamometer.

[1] Rogers, F. R. Tests and Measurement Programs in the Redirection of Physical Education, pp. 147-153.

[2] ibid., p. 147. [3] ibid., p. 148. [4] ibid., p. 148.

(d) *Arm pulling force*—recorded in pounds of force as measured by the dynamometer while the subject was standing with the chest against the end of the long horse, the height (in order to obtain a sufficient height adjustment for tall subjects, place base of horse on stall bars, benches or mats piled twelve inches high) of the horse adjusted so that the top of horse was on a level with the arm pits, with the arms extended and grasping the handles of the dynamometer, length of chain adjusted to secure maximum reach. (See Plate I, p. 49.) Two trials were given, the best pull was taken as the record.

(e) *Arm pushing force*—recorded to the nearest pound of force as measured by the dynamometer while the subject was standing with his back to the end of the long horse, the height of horse adjusted so that the top of horse was on a level with the top of shoulders, with the arms partially extended and grasping the rings of the attachment on the handle of the dynamometer. The length of the dynamometer chain was adjusted so that the arms started the push bent at an angle of 135 degrees. (See Plate II, p. 50.) Two trials were given, the best arm push was taken as the record.

Force index—This index was computed by simply adding together the number of pounds achieved by the subject in the five tests weighed equally described above. (See discussion in Chapter III.)

3. *Velocity index* (See discussion in Chapter IV.)—This index was developed as a measure of the accelerating potentiality of the large muscle groups during a unified action of the body as a whole. In the physical sense velocity equals distance per unit of time. Velocity as measured in a vertical direction varies directly as the square root of the distance, but for the practical purposes of this study it was not found necessary to use square roots of distances since measuring amounts of distance alone served to discriminate between the subjects on the basis of velocity. The Velocity Index is simply the maximum vertical distance a subject can project his own weight up in the air. The test was first used by Dr. Sargent[5] and has been used in modified forms by recent investigators, namely, Bovard and Cozens,[6] Schwegler and Englehardt,[7] L. W. Sargent.[8]

[5] Sargent, D. A. The Physical Test of a Man, 26:188.

[6] Bovard, J. F. and Cozens, F. W., The Leap-Meter, pp. 1-119.

[7] Schwegler, R. A. and Englehardt, J. L., A Test of Physical Efficiency, 29:501.

[8] Sargent, L. W. Some Observations on the Sargent Test of Neuromuscular Efficiency, 29:47.

Extensive experimentation carried on by this investigator over a three year period established the first of the following methods of measuring the Vertical Jump as the most reliable and objective. (See Chapter IV.)

(a) *Vertical jump*—Measured with the MacCurdy *Vertical Jump-Meter (See Plate V, p. 53) with the following instructions to the subject, "Squat down until your upper leg makes a right angle with your lower leg. From this position you will jump vigorously upward using your arms to help you by throwing them upward during the jump and pulling them down vigorously to a thrust position as you stretch the neck and straighten the whole body from the top of your head to your toes. You will do better if you hold the chin down." The examiner demonstrated. Five jumps were taken and the best jump was recorded to the nearest quarter inch. The zero reading was taken with the subject standing erect with cord attached to adjusted head harness before the first jump and rechecked after final jump. The subject stood in a one foot square painted on the floor to ensure a perpendicular position of the cord from head to lever arm.

(b) *Vertical jump*—recorded to the nearest half inch as measured by the "shadow method." The testing apparatus consisted of a white oil cloth wall scale lined off with inked lines one-half inch apart, an adjustable reflecting light (150 watt) placed one hundred feet from the wall scale. A tight fitting bathing cap was placed over subject's head to pull the hair down and assure a clear-cut shadow. Before the jumps the light was adjusted to a height corresponding to a point one foot above the uppermost point of the shadow cast by the top of the subject's head. The subject stood erect with his right side toward the wall scale as close to the wall as possible without interfering with the free swinging of the arms. During the jumps a pointer was used by the examiner to indicate the best jump on the scale. The difference between the point cast by the shadow of the subject's standing height and the point cast by the height of the best jump was the score. Five jumps were allowed each subject. The same instructions were given each subject as in (a) Vertical Jump described above.

(c) *Vertical jump*—recorded to the nearest half inch as measured

* This machine was designed and constructed by the author with certain helpful suggestions by C. H. McCloy and ideas gained from a study of the Bovard and Cozens Leap-Meter.

by the "jump and reach" method. The same instructions as to the mechanics of the jump were used as in (a) Vertical Jump described above. The zero measurement was taken as the subject's standing upward reach on the black oil cloth wall scale while he faced the wall with both arms upward stretched, heels flat on floor. The examiner placed his hands behind shoulders of subject exerting uniform pressure to insure maximum reach for the zero measurement. Chalk dust was used on finger tips as an aid in measuring. During the jump the subject stood sidewise to the wall scale. The difference between the height, the tip of the middle fingers in the standing reach position and the height of the tip of the middle finger of the right hand at the height of the best jump out of five was taken as the record. (A variation of the above "jump and reach" method was tried out by using a ¾" piece of chalk to mark height on a blank wall. This method was thrown out because of low reliability.) (See reliability table in Chapter II on the Velocity Index.)

(d) *Vertical jump*—This method will be referred to as the "spring tape" method. The height of the jump was measured by attaching a six-foot steel spring tape to the floor and attaching the end to the subject's belt at the hip. The method appeared simplest of all methods but was discarded when it was found that an imaginative subject could "beat it" by giving the hip on the side of the tape an extra "hunch" at the top of the jump.

(e) *Vertical jump*—An alternate form of method (a) Vertical Jump, was tried out by attaching the cord to the back of subject's belt. This method was discontinued for reasons similar to the one stated in (d) above. It was found that the belt was subject to slipping down and at the height of the jump, an enterprising subject was inclined to bend at the waist and raise the buttocks.

4. *Athletic performance indices* (A) *1928 athletic performance battery.*

A-1. 10 sec. *run*—recorded in yards as the distance run in 10 seconds. This test was administered by laying off the 100 yard straightaway with lines one yard apart across the track from the 50 yard line to the 100 yard line. The examiner started the stop watch the instant the runners left the starting mark. Three observers watched the advance foot of each runner at the end of ten seconds, signaled by a short toot on the examiner's whistle. If any two observers disagreed by more than two yards, the subject ran the trial over. Two trials were allowed with sufficient rest between. The best

record was taken as the score of the subject. By this method several subjects could be tested at the same time.

A-2. *Running high jump*—recorded in inches to the nearest inch. Regulation Field and Track Rules were followed in this event. To speed up administration three sets of standards were used.

A-3. *Running broad jump*—recorded in feet and inches to the nearest inch. Three trials were allowed. The best jump was recorded as the subject's score.

A-4. *Eight pound shot put*—recorded to the nearest foot. The subject was restricted to the standing put without any hop.

The *1928 Athletic Performance Index* was computed for each subject by taking the sum of the T-Scores[9, 10] in each of the four events with the run score taken twice. Rogers[11] found that weighting or adding more tests to this battery did not improve its validity to any marked extent.

(B) *1929 athletic performance index.*

B-1. *100 yard dash*—recorded in seconds and fifths to the nearest fifth. This test necessitated testing the subjects one at a time.

B-2. *Running high jump*—the same technique was followed as in (A-2) 1928 described above.

B-3. *Standing broad jump*—recorded in feet and inches to the nearest inch. Regulation Track and Field Rules were followed in giving this test. The best of three trials was taken as the subject's score. The jumping was done on a rubber mat without any take-off board.

B-4. *Eight pound shot put*—this test was administered in the same way as (A-4) 1928 described above.

The 1929 Athletic Performance Index was computed in two ways.

1929 A.P.I. No. 1 was the sum of the T-Scores in the four events.

1929 A.P.I. No. 2 was computed from the McCloy[12] Tables. This Index is the sum of the points achieved in the four events.

(C) *1931 Modified Cozens[13] athletic performance index.*

C-1. *Ten second run*—recorded as the number of yards run in

[9] Brace, D. K., A Method of Constructing Athletic Scoring Tables, Am. Phys. Ed. Review, April 1924.

[10] McCall, W. A., How to Measure in Education, Ch. X.

[11] Rogers, F. R. Physical Capacity Tests in the Administration of Physical Education, pp. 47-48.

[12] McCloy, C. H., The Measurement of Athletic Power, Appendix.

[13] Cozens, W. C. The Measurement of General Athletic Ability in College Men, pp. 133-139.

ten seconds. This test was administered in the same manner as test A-1, 1928 Ten Second Run.

C-2. *Standing broad jump*—recorded in feet and inches to the nearest inch. This test was administered in the same manner as test B-3, 1929 Standing Broad Jump.

C-3. *Eight pound shot put*—recorded in feet to the nearest foot. This test was administered in the same manner as test D-2, 1929 Eight Pound Shot Put.

C-4. *Dodge run*—the Cozens'[14] technique was followed in administrating this test, with the following exceptions. First, six sets of hurdles were used, so that six individuals could be tested at the same time; second, the subject's record was taken as the number of yards covered around the hurdles in twenty-two seconds. (It was found by experimentation that the best subject in this group could not complete the two round trips required within the time limit.) Three observers noted the advance foot of each subject as the short toot of the timer's whistle signaled the end of the trial. Two trials were allowed. The best record was taken as the subject's score.

C-5. *Dip (arm pushups)*—The scores achieved in this event from the Rogers[15] Strength Tests were used. The subject jumps to an arm support position at the end of the parallel bars (bars at shoulder height), arms fully extended. From this position the subject lowers the body to a right angle arm bend position and pushes up to first position. The score is the number of times a subject pushes up to straight arm position, counting one for jumping from floor to position on bars.

C-6. *Football punt for distance*—recorded as the number of yards to the nearest yard. Cozens'[16] technique was used.

C-7. *Baseball throw for distance*—recorded in yards to the nearest yard. The Cozens'[17] technique was adhered to with the exception that a regulation outdoor baseball was used.

The Modified Cozens' Athletic Performance Index was computed by T-Scaling the seven tests described above and taking the sum of the T-Scores weighted as follows: Running—1.2, Standing Broad Jump—1.0, Eight Pound Shot Put—1.0, Dodging—1.0, Dip—.6, Football Punt—1.0, Baseball Throw—1.5. (These weights were accepted after a comparison of the performances of the college and

[14] ibid., p. 138.
[15] Rogers, F. R., op. cit., pp. 149-150.
[16] ibid., p. 134.
[17] ibid., p. 134.

high school groups and in light of the findings from the data presented in Chapter III.) The original Cozens Test included seven events, 440 Yard Run—1.2, Standing Broad Jump—1.0, Dodging—1.0, Dip—.6, Football Punt—1.0, Baseball Throw—1.5, Long Dive —.7; weighted as indicated.

D. *Basketball index*—This index was developed as a measure of actual playing skill in a team game that required speed, strength and skill. The procedure was as follows:

1. The boys of each physical education class were told that a basketball tournament would take place lasting for five weeks. The object of the tournament was to give each boy a chance to show his playing ability so that a basketball grade could be given to each one.

2. Each class selected the boys they thought would make the best basketball team leaders. Enough leaders were selected in each class so that by the choosing process approximately eight boys made up each team.

CHART I

DISTRIBUTION OF BASKETBALL RANKS BY STUDENT AND FACULTY JUDGES

Class	*Rank*		*Frequency*
E	1 o		1
	2 xo	1	2
	3 xxxoxxxx	8	4
	4 xxxxoxxxxxxx	12	5
D	5 xxxxxxoxxxxxxxxx	16	7
	6 xxxxxxxxxxxxxxxoxxxxxxxxxxxxx	29	16
	7 xxxxxxxxxxxxxxxxxxxoxxxxx	25	20
	8 xxxxxxxxxxxxxxxxxxxxxxxxxxxxoxxxxxxxxxxxxxxxxx	46	29
C	9 xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxoxxxxx	41	36
	10 xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxoxxxx	48	44
	11 xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxoxxx*	51	48
	12 xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxoooooo*	43	50
B	13 xxxxxxxxxxxxxxxxxxxoooooooooooooooo	19	35
	14 xxxxxxxxxxxxxxxxxxxoooo	19	23
	15 xxxxxxxxxxxxxoooooo	13	19
	16 xxxxoooooooo	4	12
A	17 xxxxxoooooo	5	10
	18 xoooooo	1	7
	19 xxoo	2	4
	20 xxo	2	3
		N = 375	375

* Note: (x)—cases judged by students.
(o)—cases judged by faculty.

RESULTS OF STUDENT JUDGES (EIGHT)

	A	*B*	*C*	*D*	*E*
Theoretical Class Per Cents	5%	20%	50%	20%	5%
" Frequencies	18	75	189	75	18
Obtained Frequencies	10	55	183	116	21
Deviations	—8	—20	—6	+41	+3

RESULTS OF FACULTY JUDGES (TWO)

Obtained Frequencies	24	89	178	72	12
Deviations	+6	+14	—11	—3	—6

3. Eaeh elass was given specifie instructions on rating eaeh other with the following points emphasized:

(a) At the end of the five weeks playing period each player will rate every other player on his squad ineluding himself. (This plan yielded ten judges, including the instruetors, on eaeh individual.)

(b) A normal eurve was presented to all classes, explaining that only varsity players, the best of the varsity reserves and any other players of marked ability would be expeeted to reeeive a ranking of A; only the better players of the inter-home league would reeeive a ranking of B; only the better players of the tournament teams would reeeive a ranking of C; only the better substitutes of the tournament teams would receive a ranking of D; and only the poorest players of the tournament teams would reeeive a ranking of E.

(e) The ranking letters were designated as A = superior, B = good, C = average, D = below average and E = poor.

(d) All opinions were to be kept seeret until the end of the five weeks.

4. Substitutions were so arranged that even the poorest substitute got an equal ehanee to play.

5. The judges were helped in their estimates by a seven minute shooting, dribbling and passing drill before eaeh game.

6. At the end of the five weeks eards were passed out one to each player. All were instrueted to place the names of the players on their squad, ineluding their own, on the card. The normal eurve was again referred to and each elass was shown that each of the five eategories A, B, C, D, and E would be divided into four grades. This division gave seores from one to twenty, with one the lowest and twenty the highest. The boys were then instrueted to go off by themselves and plaee a grade after eaeh name on their squad list. The instruetor placed his estimated grades on his roll cards.

7. The eight student judgments for each individual were averaged and this figure taken as the subject's Basketball Index.

The frequency distribution curve in Chart I, page 13 indicates how the three hundred and seventy-five cases were grouped. Assuming that basketball ability is represented by the "normal curve," it would appear that the students tend to underrate and the instructor tends to overrate. (See Chart I.) The theoretical percentages set up were A's—5%, B's—20%, C's—50%, D's—20%, and E's—5%. Chart I shows how near the actual groupings approximated the theoretical groupings.

The validity of the ratings was tested by choosing teams from the four adjoining divisions, matched as follows: 4 vs. 5, 8 vs. 9, 12 vs. 13, and 16 vs. 17 (team 16 had to choose one member from the 15's and team 17 had to complete their team from the 18's). Each pair played a series of three games. The results were as follows:

	17 vs. 16	*13 vs. 12*	*9 vs. 8*	*5 vs. 4*
Scores	20—8	12—8	11—8	7—6
	16—9	16—15	13—10	13—8
	22—6	11—6	9—11	8—4

E. *Motor ability.* 1. The Brace[18] Test of Motor.

The following are the twenty tests that make up the Brace Motor Ability Index. The score is the number of tests passed successfully. Ability was selected and administered according to the Brace[19] technique. Two applications of the test were given during this same week and the best score of each subject taken as his Motor Ability Index.

Test 1. Walk in a straight line, placing the heel of one foot in front of and against the toe of the other foot. Start with the left foot. Take 10 steps in all, 5 with each foot. Eyes open.

Test 2. Stand. Jump into the air and clap both feet together once, and land with the feet apart (any distance).

Test 3. Lie flat on the back on the floor. Fold the arms across the chest. Raise the trunk to a sitting position. Do not raise the feet above the floor, or unfold the arms.

Test 4. Fold the arms behind the back. Kneel onto both knees. Get up without losing the balance or moving the feet about.

Test 5. Take a front leaning rest position, i.e., place the hands on the floor, arms straight, extend the feet back along the floor until the body is straight

[18] Brace, D. K., Measuring Motor Ability, Test Booklet, pp. 100-128.
[19] ibid., Ch. VIII. (See key p. 5)

(in an inclined position to the floor). Bend the arms, touching the chest to the floor, and push up again to straight arms. Do this 3 times in succession. Do not touch the floor with the legs or waist.

Test 6. Squat on the heels with feet together and knees out, and hands between the knees with fingers touching the floor. Spring up onto both heels, with legs straight and toes up, and swinging both arms out at the side level with the floor. The feet should then be about 18 inches apart. Head up. Repeat this exercise three times (in all) rhythmically.

Test 7. Stand with feet together. Jump into the air and make a full turn to the left, landing on the same spot. Do not lose the balance or move the feet after they strike the floor.

Test 8. Jump into the air and clap the feet together twice and land with the feet apart (any distance).

Test 9. Stand on the right foot. Grasp the left foot behind the right knee. Bend and touch the left knee to the floor, and stand up without touching any other part of the body to the floor, or losing the balance.

Test 10. Hold the toes of either foot in the opposite hand. Jump up and jump the free foot over the foot that is held, without letting up.

Test 11. Jump into the air and slap both heels with the hands behind the back.

Test 12. Stand, kick the right foot up so that the toes come at least level with the shoulders. Do not fall down on the floor.

Test 13. Stand on the left foot. Bend forward and place both hands on the floor. Raise the right leg and stretch it back. Touch the head to the floor, and regain the standing position without losing the balance.

Test 14. Stand with both feet tight together. Bend down, extend both arms down between the knees, around behind the ankles, and hold the fingers together in front of the ankles without losing the balance. Hold this position for five seconds. (Counted by scorer.)

Test 15. Stand with both feet together. Swing the arms and jump up in the air, making a full turn to the right. Land on the same spot and do not lose the balance, that is, do not move the feet after they first strike the floor.

Test 16. Kneel onto both knees. Extend the toes of both feet out flat behind. Swing the arms and jump to the feet without rocking back on the toes, or losing the balance.

Test 17. Fold the arms across the chest. Cross the feet and sit down cross-legged. Get up without unfolding the arms or having to move the feet about to regain the balance.

Test 18. Stand on the left foot. Hold the bottom of the right foot against the inside of the left knee. Place hands on hips. Shut both eyes, and hold the position for ten seconds, without shifting the left foot about on the floor.

Test 19. Take a squat rest position. That is, place the hands on the floor between the knees and close to the feet. Bend the elbows slightly and place both knees well over the elbows. Rock forward onto the hands, raising the feet from the floor. Support the body on the hands. Hold the position for five seconds (as counted by the scorer).

Test 20. Stand on the left foot with the right foot extended forward off of

the floor. Sit down on the heel of the left foot, without touching the right foot or hands to the floor. Stand full up without losing the balance.

Reliability

A test or measurement to be considered reliable should show a self r of at least .80. Makers of intelligence tests usually require a product moment coefficient of .90 or above between the scores of two applications of the test given to the same group, under identical conditions. Garrett[20] states, "To be a reliable measure of capacity, a mental or physical test should—generally speaking—have a minimum reliability coefficient of at least .80 . . . the size and variability of the group measured should always be stated." For the above reasons test scores of a group limited to the same chronological age would yield a more significant reliability coefficient.

Table I shows the reliability coefficients (Pearson[21] r's) of the individual and group tests. The following letters above the coefficient columns in the table indicate the investigators reporting same or similar data:

M. = MacCurdy, H. L.
R. = Rogers, F. R.
McC. = McCloy, C. H.
C. = Cozens, F. W.
B. = Brace, D. K.

TABLE I

RELIABILITY COEFFICIENTS

Test	*Age Range***	*No. Cases**	*M*	*R*	*C*	*B*	*McC*
Weight	14-16 yr.	100	.98				
Height	"	100	.99				
Sh. Breadth	"	100	.95				
Ch. Breadth	"	100	.89				
Hip Breadth	"	100	.95				
Ch. Depth	"	100	.94				
Rogers Strength Index	16-20 yr.	220	.88	.94			
Force Index	16 yr.	103	.95				
Grips	"	103	.94	.92			
Leg Strength	"	103	.82	.86			
Back Strength	"	103	.88	.88			
Lung Capacity	"	103	.92	.97			
Pullups	"	103	.85	.91			.784

[20] Garrett, H. E., Statistics in Psychology and Education, p. 269.
[21] Pearson, Karl, Product-moment correlation coefficient.

TABLE I *(Continued)*

Test	*Age Range***	*No. Cases**	*M*	*R*	*C*	*B*	*McC*
Pushups	"	103	.81	.92			.726
Arm Pull	"	103	.96				
Arm Push	"	103	.94				
Vertical Jump (a)	16-20 yr.	220	.98				
" " (b)	"	100	.92				
" " (c)	"	100	.93		.96		
" " (d)	"	100	.87				
" " (e)	"	100	.85				
10 Sec. Run	"	201	.82				
Running H. Jump	"	220			.97		.737
Running B. Jump	"	220	.79		.90		.736
8# Shot Put	"	220	.91				.802
100 yd. Dash	"	220	.87		.97		.794
Standing B. Jump	"	220	.91		.97		.699
Dodge Run	16 yr.	103	.76		.85		
Football Punt	"	103	.70		.82		
Baseball Throw for Distance	16 yr.	103	.83		.91		
Couzens Index					.97		
Modified Couzens Index	16 yr.	103	.90				
Brace Motor Ability Test	16 yr.	103	.78			.82	

* No. of cases applies only to column M.

** Age Range applies only to column M.

SUMMARY

1. One thousand four hundred and fourteen cases were used in the different phases of this study.

2. A wide variety of physical tests were experimented with, comprised of structure measurements, tests of strength, motor ability; game skills and athletic performance.

3. Objectivity was partly established by consistent agreements between the results obtained by instructor and student assistants.

4. In most cases where an instrument was used, the readings were checked for accuracy by a second observer.

5. All measuring instruments were checked frequently for accuracy.

6. The reliabilities of the various tests and measurements were acceptably high and compared favorably with similar reliabilities reported by other investigators.

7. Several readings of an instrument were used in arriving at a score.

CHAPTER III

THE MUSCULAR FORCE INDEX

Definition. Millikan and Gale[1] state, "That in a physical sense we should use the simple terms 'gram, or 'pound' to denote exclusively an amount of mass (weight) and use the full expression 'pound of force' wherever we have in mind the pull of the earth upon this mass." The human body can exert force in two ways, first, by virtue of its weight (pounds) and second, by the ability of the muscles to overcome resistance.

Measurement. The amount of muscular force can be accurately and easily measured by the use of dynamometers[2] constructed for this purpose. The measurement of muscle strength[3] (force) is not a new technique. The most recent study of muscle strength was made by Rogers[4] in 1925, and according to this investigator grew out of his experiences in "taking the Harvard Strength Test" as devised by Sargent[5] nearly forty years ago. For a number of years Kellogg[6] used his universal dynamometer with which he tested the strength of a large number of muscle groups, both small and large. In the search for a Force Index that would be representative of the large muscle forces used in the activities of our modern programs of Physical Education, the investigator set up the following criteria:

1. The measure should be one that could be expressed in pounds of force.

2. The forces measured should be those that are used in the fundamental movements of our vigorous games and sports, as running, leaping high and far, pushing, pulling and throwing.

3. The complete test should be one easily understood and saving in the time of both examiner and students.

[1] Millikan, R. A. and Gale, H. G., Elements of Physics, p. 62.

[2] Standard instruments, manufactured by the Narragansett Machine Company, Providence, R.I.

[3] In Physical Education the terms strength and force have been used interchangeably.

[4] Rogers, F. R., Physical Capacity Tests in the Administration of Physical Education, pp. 1-93.

[5] Sargent, D. A., Reported in 1884, Harvard University.

[6] Kellogg, J. H., Sanitarium, Battle Creek, Mich.

4. The test should not put a premium on skill. It should not favor the physically skillful.

The possibilities of using the Rogers[7] Strength Test as a measure of muscular force was investigated. This test probably satisfies the requirements of the second and third criteria but fails to meet the first in so far as the total strength index is obtained by adding *cubic inches* of lung capacity to *pounds* of force achieved by grips, legs and back, to *points* achieved by arm "pullups" and "pushups." In order to obtain a measure of force, it was decided to drop out the test of lung capacity and change the arm tests, so that arm force could be measured in pounds. The final battery of force tests selected was: 1. Back Force; 2. Leg Force; 3. Grip Force; 4. Arm Pulling Force; 5. Arm Pushing Force. The sum of the number of pounds of force achieved by the subject in the five tests was called the Force Index.[8]

In connection with the selection of the final Force Index, the test of lung capacity was dropped for the following reasons:

1. Lung capacity as measured in cubic inches did not lend itself to the force index as measured in pounds of force where computations were necessary.

2. The final Force Index with lung capacity dropped out had a higher degree of correspondence with athletic achievement than the Rogers Strength Index had with athletic achievement with the lung capacity included.

The Rogers Arm Test Formula was modified into two tests of Arm Pulling Force and Arm Pushing Force for the following reasons:

1. Arm pulling and arm pushing are more natural athletic movements than chinning and dipping.

2. The degrees of correspondence between Arm Pushing Force and Arm Pulling Force and athletic achievement were much higher than the correspondence between the Rogers Arm Formula and athletic achievement. (See Table II, p. 24.)

Before the Force Index was accepted, it was necessary to show that it was a valid measure of the kind of muscular force found in athletic ability. The findings were based on the following assumptions:

1. Probably the best criterion of athletic ability is a high degree

[7] ibid., p. 4.

[8] Plates and descriptions are found in Chapter VI, pp. 49-54.

of proficiency in the sports (actually playing the game). By this criterion those awarded varsity letters in one or more interscholastic athletic sports were compared with those not earnings these awards. This criterion was called athletic achievement to distinguish it from the other criterion chosen, that of athletic performance (battery scores on running, jumping, throwing, etc.)

2. That kind of force found in athletic movements would probably be centered in the forces of the legs, thighs, back, arms and hands or more specifically, those forces used in vigorous starts, stops, dashes, throws, pulls and pushes of game action.

Procedure

1. It was necessary to find the degrees of correspondence existing between the criteria and the measured forces.

2. The boys of the same chronological age (16 year olds) were chosen as the experimental group. Bi-serial and product-moment r's were computed.

The following conclusions were drawn from the findings presented in Tables II and III, p. 24.

1. From these findings it was evident that the Force Index and athletic performance (Index C see description in Chapter II) correlated* to the degree of .57, whereas the correlation between strength (Rogers) and athletic performance was .64 and between strength and the Force Index was .84. Of the two measures, the Rogers Strength Index and the Force Index, it appeared from the data that Strength was the better. However, further analysis showed that the factor of weight was more potent in the Rogers Strength Index than in the Force Index. The two variable correlations were:

$$\text{Weight vs. Strength} = .60 \pm .04$$
$$\text{Weight vs. Athletic Performance} = .33$$

By holding the factor of weight constant and using the partial correlation[9] technique, the coefficient for Rogers Strength and Athletic Performance was r S.A. (Wt.) = .59. This coefficient represents the degree of correspondence between strength and athletic performance with the influence of weight partialed out. In a like manner the degree of correspondence between force and athletic performance with weight partialed out was:

* Product-Moment Correlation Coefficients.

[9] See Appendix under statistical methods.

r F.A. (Wt.) = .52
as
Wt. vs. Force Index = .38
Athletic Performance vs. Force Index = .57

On this data (103 sixteen year olds) where the conditions of rectilinearity were satisfied the Rogers[10] method of comparing the predictive values of correlation coefficients may be used. Where (1) represents athletic performance, (2) represents strength, (3) represents weight, and (4) represents force, the correlation coefficients reduced to predictive indices $(1-\sqrt{1-r^2})$ would be:

$r_{12} = .64 = P.I. = .23$
$r_{13} = .33 = P.I. = .06$
$r_{23} = .60 = P.I. = .20$
$r_{14} = .57 = P.I. = .18$
$r_{34} = .38 = P.I. = .08$

From the above data it may be concluded that the Rogers Strength Index is 87% weight (ratio of .20 to .23) whereas the Force Index is only 44% weight (ratio of .08 to .18).

The higher validity of the Force Index as a measure of athletic achievement (see key p. 3) was further substantiated from the findings presented in Table III. In this analysis athletic achievement was accepted as the criterion and bi-serial was used as the method to show relationships. On the 1931 data (16 year olds) it was found that force combined with velocity was a better measure of athletic achievement than strength combined with velocity. The respective correlation coefficients were .88 $\pm$ .03 and .85 $\pm$ .03. Also the Force Index was a better measure of athletic achievement than strength (Rogers); the correlation coefficients (bi-serial) were .76 and .72.

Reliability

The final factor that raised the estimation of the Force Index was the high reliability obtained. Table I shows the reliability coefficient for the Force Index to be .95 whereas the best reliability obtained on the Strength Index was .89.

Sampling of Big-Muscle Forces

In the selection of the tests of muscular force the findings re-

[10] Rogers, F. R., op. cit., pp. 13-15.

ported by Schmidt and Kohlrausch[11] (translated from the German by Sputh) helped to substantiate the sampling of muscle forces. Laboratory experiments on the muscles of the human body showed that: 1. Muscle weight accounts for one-half of the total body weight; 2. One-half or about 56 per cent of this muscle bulk is found in the muscles of locomotion, namely, those of the pelvis and thighs, and about 28 per cent of the total muscle weight is found in the muscles that move the arms (trunk, arm and hand muscles). Add to the above mentioned muscle groups (84%) the muscles of the lower legs and practically all of the muscle weight has been accounted for in the sampling.

Influence of Height

Bowen and McKenzie[12] state that the amount of muscular work is conditioned by two factors of equal importance; the amount of force used and the distance through which this force acts. The mechanical law of work is stated mathematically as, Work equals Force times Distance. These facts would indicate that the height of an individual would strongly influence muscle force, as the muscles of a tall individual would be proportionately longer, thereby working through greater distances. However, it is known that tall individuals are at a disadvantage in athletic activity unless they have adequate cross-section of muscle to go with their height. Strength (Force) varies directly as the cross-section of muscle area. The data from Table II explain this influence by actual figures. The respective degrees of correspondence between athletic performance and weight and height are represented by the correlations of .33 and .35. It is concluded from these findings that the adequate sampling of big-muscle force found in the Force Index will account for both height and weight (muscular). The correlation between the Force Index and weight is .38. Ideally we would desire to find the same degree of correlation between force and weight as between weight and athletic performance, provided these coefficients are low in relation to the correspondence between the Force Index and Athletic Performance.

[11] Schmidt, F. A. and Kohlrausch, W., Physiology of Exercise, pp. 54-71.
[12] Bowen, W. P., and McKenzie, R. T., Applied Anatomy and Kinesiology, pp. 21-22.

TABLE II

PRODUCT-MOMENT CORRELATION COEFFICIENTS BETWEEN TWO VARIABLE COMBINATIONS AS INDICATED

(1931 Data—16 year olds—103 Cases)

Force Index		*Rogers Strength Index*	
Weight	.38	Weight	.60
Athletic Performance	.57	Athletic Performance	.64
Rogers Strength Index	.84	Force Index	.84
Ten Second Run	.54		
Standing Broad Jump	.55	*Modified Cozens Athletic Performance Index*	
8 Pound Shot Put	.62		
Dodge Run	.21	Weight	.33
Distance Football Punt	.06	Height	.35
Distance Baseball Throw	.32	Chinning	.34
		Pushups	.42
		Arm-Pulling Force	.57
		Arm-Pushing Force	.49
		McCloy Classification Index	.35
		Vertical Jump No. 1	.68

TABLE III

BI-SERIAL CORRELATION COEFFICIENTS BETWEEN PHYSICAL TESTS AND ATHLETIC ACHIEVEMENT

Tests	*Year*	*No. Cases*	*Age Group*	r(bis)
Weight	1928	201	15.5-20	.45
Age (15.5-20 years)	1928	201	15.5-20	.45
Ath. Performance Index	1928	201	15.5-20	.84
Rogers Strength	1928	201	15.5-20	.64
Vertical Jump No. 2	1928	201	15.5-20	.72
10 Second Dash	1928	201	15.5-20	.73
8 Pound Shot Put	1928	201	15.5-20	.81
Running Broad Jump	1928	201	15.5-20	.72
Running High Jump	1928	201	15.5-20	.55
Phys. Cap. Index No. 2 (Strength + Vert. Jump	1928	201	15.5-20	.76
Phys. Cap. Index No. 3 (Strength × Vert. Jump)	1928	201	15.5-20	.88 ± .03
Weight	1929	238	15.5-20	.44
Height	1929	233	15.5-20	.49
Age	1929	233	15.5-20	.48
McCloy Ath. Performance I	1929	222	15.5-20	.77
"T"-Score Ath. Performance I	1929	222	15.5-20	.79
Rogers Strength	1929	222	15.5-20	.83
Vertical Jump No. 1	1929	222	15.5-20	.84

TABLE III *(Continued)*

Tests	*Year*	*No. Cases*	*Age Group*	r(bis)
18 Ft. Rope Climb	1929	107	15.5-20	.36
Standing Broad Jump	1929	225	15.5-20	.76
Running High Jump	1929	226	15.5-20	.56
8 Pound Shot Put	1929	224	15.5-20	.69
80 Yard Dash	1929	224	15.5-20	.65
Phys. Cap. Index No. 2	1929	222	15.5-20	.85
Phys. Cap. Index No. 3	1929	222	15.5-20	.93 ± .03
Weight	1931	218	15.5-19.5	.47
Height	1931	214	15.5-19.5	.41
Age (15.5-19.5 years)	1931	218	15.5-19.5	.47
Dodge Run	1931	206	15.5-19.5	.49
Standing Broad Jump	1931	262	15.5-19.5	.62
8 Pound Shot Put	1931	253	15.5-19.5	.54
10 Second Dash	1931	242	15.5-19.5	.70
Baseball Distance Throw	1931	252	15.5-19.5	.81
Football Distance Punt	1931	232	15.5-19.5	.45
Back Strength	1931	266	15.5-19.5	.49
Leg Lift	1931	262	15.5-19.5	.29
Best Grip	1931	261	15.5-19.5	.44
Arm Pull-ups	1931	261	15.5-19.5	.24
Arm Push-ups	1931	259	15.5-19.5	.33
Lung Capacity	1931	263	15.5-19.5	.61
Phys. Cap. Index No. 3	1931	204	15.5-19.5	.85 ± .03
Brace Motor Ability	1931	214	15.5-19.5	.27
Age (15.5-20 years)	1928-31	627	15.5-20	.44 ± .03
Phys. Cap. Index No. 3	1928-31	627	15.5-20	.90 ± .02
Energy Index (Wt. x V.J.)	1931	222	15.5-19.5	.76
Rogers Strength	1931	103	16	.72
Vertical Jump No. 1	1931	103	16	.67
Force Index	1931	103	16	.76
Mod. Cozens Ath. Performance	1931	103	16	.78
Energy Index (Wt. x V.J.)	1931	103	16	.70
Basketball Index	1931	103	16	.42 ± .08
Phys. Cap. Index No. 3 (Strength x Vert. Jump)	1931	103	16	.85 ± .03
Phys. Cap. Index No. 1	1931	103	16	*.88 ± .03
Phys. Cap. Index No. 1	1931	104	17 (Comparison)	.86 ± .03

*Probable errors of bi-serial r's.

SUMMARY

1. The development of the Muscular Force Index grew out of experiments with the Rogers Strength Index.

2. After certain modifications the Force Index became the sum of the maximum muscular achievement by the forces of the legs, back, hands and arms.

3. The Force Index is expressed as the number of pounds of force as measured by the dynamometers.

4. The Force Index was found to be a more valid measure of athletic ability than the Rogers Strength Index, as indicated by the Biserial r coefficients of .76 and .72 respectively.

5. The reliability of the Force Index was found to be .95.

6. The Force Index adequately samples the big-muscle forces of the human body.

7. The influence of height and weight on the athletic performance of 16 year old boys was represented by the correlation coefficients of .35 and .38.

8. The correlation between the Force Index and athletic performance yields a coefficient of .57 and between the Force Index and Weight we found a degree of correspondence of .38.

CHAPTER IV

THE MUSCULAR VELOCITY INDEX

Definition

Velocity in a muscular sense as used in this study means the ability of an individual to apply force with maximum acceleration. It is known that individuals differ greatly in this respect, some have fast reactions and others slow reactions. From a well known mechanical law, Power = "Force times Velocity." Also the amount of mechanical work done by a body depends on the space (distance) through which a given force acts. In a lay sense an individual is powerful if he has the ability to apply maximum force over a given distance with maximum speed (velocity).

In the search for an index that would be representative of a maximum degree of acceleration (explosiveness) the following criteria must be satisfied.

1. It should be a test of such a nature, that it will measure the results in terms of the body acting as a cooperating whole.
2. The test should be easy to measure and simple to execute.
3. Measurement of results should be in terms of rate or distance.
4. The test should be expressive of that kind of action, driving power or explosiveness that is required in the fundamental movements of our vigorous games and sports. (Big muscle groups.)
5. The test should not favor the physically skillful in so far as requiring skill of execution.
6. The test should be economical in the use of examiner's and student's time.

The test of muscular velocity finally selected after three years of experimentation was the "Vertical Jump." (See Plate V, p. 53. Description in Chapter II, pp. 9-10.) It is necessary to show that this test is a valid measure of muscular velocity and that it satisfies all of the criteria set-up above. First, however, it is well to state that other choices were examined such as the 80 yard dash (foot speed), 8# shot put (arm speed), baseball throw for dis-

tance (arm speed) and tapping rate (Dunlop reaction time). It is obvious that the last is unsuitable for big muscle reactions. The 80 yard dash, shot put, and baseball throw correlate high with athletic performance and athletic achievement, but were not acceptable because of the influence of training.

The actual measuring of the vertical jump proved to be the biggest problem. The construction of the Vertical Jump-Meter supplied an accurate instrument and with its use the reliability and objectivity of measurement was highly satisfactory. Five different methods were used in experimentation. They are described in detail in Chapter II under description of tests.

TABLE IV

PRODUCT-MOMENT CORRELATION COEFFICIENTS BETWEEN TWO VARIABLE COMBINATIONS AS INDICATED

(1931 Data—16 year olds—103 Cases)

Vertical Jump

(Velocity)

Weight	.23	Dodge Run	.30
Height	.25	Football Punt	.15
Leg Force	.30	Baseball Throw	.41
Back Force	.46	Trunk Length	.22
Grip Force	.42	Thigh Length	.22
Arm Force (Pulling + Pushing)	.44	Leg Length (lower)	.10
Ten Second Run	.66	Chest Breadth	.38
Standing Broad Jump	.70	Arm Reach	.29
8 Pound Shot Put	.54	Modified Cozens Athletic Index	.68

Procedure

The statistical method was chosen as a method of analysis. A summary of the findings is presented in Table IV, above. It was necessary to show that the jump as measured by the vertical jump-meter satisfied the criteria set forth above.

1. It is obvious that the measure does satisfy the first two criteria.

2. In satisfying the third criterion we scored results in terms of vertical distance. The mechanical law of velocity is that velocity equals distance divided by time. The velocity of a body projected vertically upward is represented by the formula:[1]

V = the square root of 2g (d)
where g is the pull of gravity and
d is the vertical distance transversed by the body

[1] Millikan and Gale, Elements of Physics, p. 85.

If an individual jumps 18 inches (1.5 ft.) his velocity, taking 2g as 64 would be 9.8 ft. per second (initial velocity). By dividing distance by rate per second it is found that the elapsed time for this individual is .15 seconds. By accepting the vertical jump as a measure of muscular velocity it is well to point out that from the standpoint of the physics involved it is a rough and practical measure, since it is assumed that the muscles are working the same length of time and with the same intensity of purpose during that time. As explained in Chapter II, p. 8 it was not found necessary to use the square root of the vertical distance jumped by the subject.

3. From Table IV the findings showed that the Velocity Index was a good measure of athletic skill providing the individual test did not require a high degree of training.

4. It was necessary to show that the jump was not unduly influenced by structure. Of the skeletal measurements taken (see Table IV, p. 28) none exerted more influence than height alone. From an unpublished study by the investigator,[2] the weight of 16 year olds was accounted for by the influence of five skeletal measures (height, shoulder breadth, chest breadth, chest depth and hip breadth). From this study it was found that chest breadth exerted the greatest influence on weight. In so far as structure is accounted for by weight and that weight does not influence performance in the jump (fatty weight would be penalized by the jump) it was concluded that no adjustment for structure was necessary.

5. The muscular forces used in the jump give a good sampling of the action of big muscle forces used in games and sports. The actual degree of correspondence between the vertical jump and athletic performance (Modified Cozens' Athletic Index) is .68 and between athletic achievement (high honor awards in interscholastic athletics) and the vertical jump it is .84 (bi-serial r see Table III, p. 24).

Reliability

The reliability of the Velocity Index as measured with the Vertical Jump meter was .98 (self r on 220 cases ranging from 16 to 20 years in age). Reliabilities on the other four methods used in measuring the vertical jump range in self r's from .83 to .92.

[2] MacCurdy, H. L., The Intercorrelations of Body Weight, Skeletal Measures and Strength of Fourteen, Fifteen and Sixteen Year Old High School Boys, Teachers College, Columbia University.

Objectivity

The objectivity of the Vertical Jump Meter as an instrument for measuring the vertical jump was established by the fact that trained student assistants obtained consistent measurements, in agreement with those of the investigator, on the same subjects.

Summary

1. The Muscular Velocity Index as developed by the investigator after three years of experimentation was taken as the difference (in inches) between an individual's standing height and the top of his best vertical jump.

2. The vertical distance jumped was measured with the Vertical Jump-Meter as developed by the investigator.

3. The Velocity Index was found to be a good index of proficiency in athletic skill, providing the skill tested did not require a high degree of training.

4. The Velocity Index was developed from the mechanical law that

V = the square root of 2g (d) where g is the pull of gravity and d is the vertical distance transversed by the body.

5. The influence of structure on the performance in the jump was no greater than the influence of structure on body weight.

CHAPTER V

THE PHYSICAL CAPACITY INDEX

Definition. In the engineer's sense the capacity of a machine for doing work is measured in units of power. The unit of power commonly used is the "horse power" expressed as the number of foot-pounds of work done in a given time. More simply, power is the engineer's activity index or the time rate of doing work.

The Physical Capacity Index as developed in this study, is the activity or power measure of an individual's "big-muscle" capacities. Using the experimental technique the investigator found that physical capacity could best be measured by the application of the mechanical principle that power equals force (muscular) times velocity (muscular). The Physical Capacity Index was computed by multiplying the Force Index (in pounds) by the Velocity Index (in inches) and dividing by 100. For example in an individual case:

Individual's Force Index =	1500
Individual's Velocity Index =	20
Individual's Power Index (Inch-Pounds)	30,000
Dividing by 100 to obtain a workable figure	
Individual's Physical Cap. Index =	300

Validity. In the search for an adequate criterion to validate physical tests, three recent outstanding studies by Brace,[1] Rogers[2] and Cozens[3] used similar methods. Brace used (a) judgment ratings by instructors, (b) battery scores on a variety of athletic events, and (c) achievement in athletic games; Rogers used (a) athletic ability tests (battery scores) and (b) success in making school teams; Cozens used the judgments of experts who determined that athletic ability was made up of the following elements: Arm and shoulder-

[1] Brace, D. K. The Measurement of Motor Ability, pp. 1-134.

[2] Rogers, F. R. Physical Capacity Tests in the Administration of Physical Education, pp. 1-93.

[3] Cozens, F. W. The Measurement of General Athletic Ability of College Men, pp. 1-192.

girdle strength, Arm and shoulder coordination, Hand-eye, foot-eye, arm-eye coordination, Jumping and leg strength, Endurance, body coordination, agility and control and speed of legs. In order to adequately sample the above elements, Cozens used a battery of forty-one tests, taking the sum of achievement on this battery as his criterion index of general athletic ability.

This investigator was fortunate in having available the findings of the studies mentioned as possible "criteria" of physical capacity. It will be seen from Chapter II that data were available on the Rogers Strength Test, Brace Motor Ability Test, and the Modified Cozens Athletic Ability Test.

Procedure

In order to gain as much information as possible relative to the merits of the various tests as measures of general athletic ability three methods of statistical technique were developed. The extent to which a test differentiates between those of earned ability (making a major sport award) from those of unearned ability (non-athletes) was measured by the use of standard difference scores[4] and bi-serial r.[5]

A standard difference score is an index of the "goodness" or the power of a test in differentiating between two groups. A bi-serial "r" is more appropriate in that it represents the *degree* of relationship. Paterson's[6] point may be well taken when he states, "The method of direct correlation should be substituted for the obtained difference method." For the above mentioned reasons no use was made of the standard difference scores.

A summary of the complete analysis is presented in Table III, p. 24.

The third method used was the product-moment correlation technique[7] applied to the scores of the various individual tests and battery combinations.

In the examination of the findings presented in Table III the following points should be considered:

1. The age range on all data was limited to the age range of

[4] The difference between the means divided by the standard deviation of this difference. Explained in Appendix under statistical procedures.

[5] Bi-serial "r" correlation coefficient between a dichotomous distribution and a quantitative distribution. (See Appendix under statistical procedures.)

[6] Paterson, D. G., Physique and Intellect, pp. 286-287.

[7] Pearsonian "r", see appendix under statistical procedures.

athletes (letter men). We find this range for the 1928 data was 15 yr. 6 mo. to 20 yrs., for the 1929 data the same, and for the 1931 data the age range of athletes was 15 yr. 6 mo. to 19 yr. 6 mo.

2. The mean age of athletes for the three groups was approximately 7 months higher than the mean age of non-athletes (those not making a major sport letter).

3. The influence of age on these data did have a spurious effect and would make all correlation coefficients higher. However, this was a constant influence on all the test scores.

4. In order to off set this spurious influence of age final major assumptions were drawn from the 1931—*16 year* data. This group was comprised of all 16 yr. olds in the 1931 group. Furthermore, the 16 yr. olds represented the chronological age closest to the mean age of the whole group (age range 12.5 to 20.0). The mean age of the whole group was 16.5.

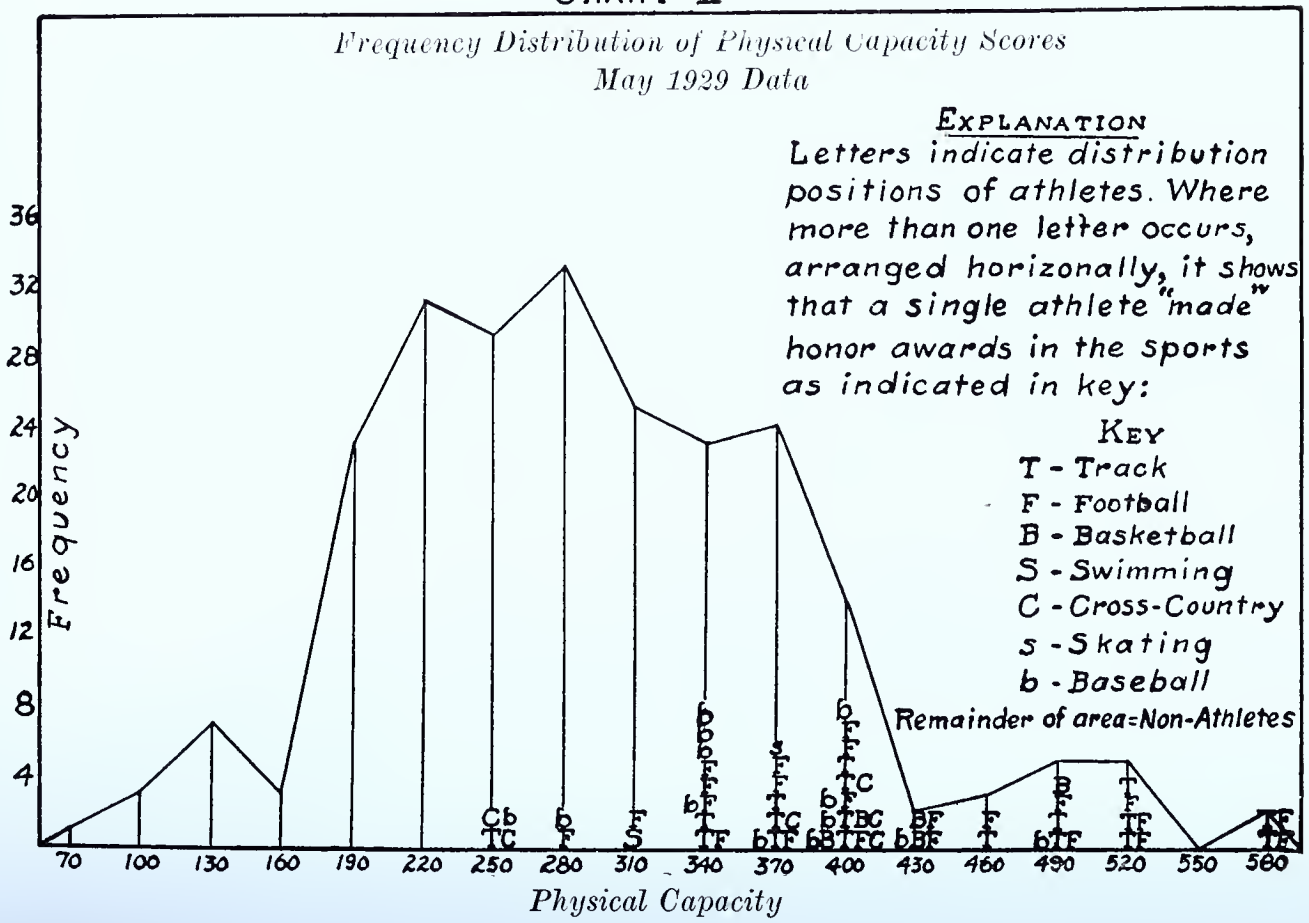
5. The athletes were all boys who "made" their letters for a given year in any of the following sports: Football, Basketball, Track, Cross-Country, Baseball, Swimming, Tennis and Skating. (Chart II p. 34 presents a typical frequency distribution of the scores of athletes and non-athletes in physical capacity.)

Analysis of 1928 Data

In the search for a more valid test of physical capacity than strength (Rogers), the possibilities of combining muscle strength with muscle velocity was investigated by the regression technique. Here, a battery of four athletic tests (ten second run, running high jump, running broad jump and the 8# shot put) was accepted as the criterion index of general athletic ability. The scores on the four events were T-scaled and added together. The sum of the T-scores, giving running a weight of two was called Athletic Performance Index No. 1 (see Chapter II). The partial correlation technique threw some light on the degree of influence the respective factors of strength (Rogers) and velocity had upon athletic performance. The correlation between strength (Rogers) and the criterion was .71, the correlation between the vertical jump (velocity) and the criterion was .76, and the correlation between strength (Rogers) and velocity was .60. The computed regression equation yielded best weighting of strength (Rogers) and velocity in predicting athletic performance. The equation found was

Chart II

Frequency Distribution of Physical Capacity Scores
May 1929 Data



Athletic Performance = (Strength Score) plus
(177 times Velocity Score)

This index was called the Physical Capacity Index No. 2 and correlated with the criterion, yielded a coefficient of .83.

The conclusion was obvious, that either muscular strength or muscular velocity taken alone is inadequate, but the weighted combination turned out to be a 33% better measure than strength alone and a 20% better measure than velocity alone in predicting athletic performance as measured by the criterion index.

Analysis of 1929 Data

At this point in the research the following hypotheses were contemplated:

1. The need of a better criterion of athletic ability.

2. The need of more accurate measurement of muscular strength and muscular velocity, principally, the latter.

To meet these ends the 1929 data were collected and a new method of combining muscular strength and muscular velocity was investigated. The theory was that in so far as capacity means power, why not make use of the principle that power equals force times velocity. The Rogers Strength Index was used as the measure of muscular force and after refining the method of measuring the vertical jump, this test was accepted as the measure of muscular velocity. The new index of Physical Capacity called No. 3, then became strength (Rogers) *times* velocity (vertical jump in inches) dividing the product by 100. The bi-serial r technique proved a means of improving the criterion of athletic ability. It was shown by this method the relative merits of all tests. The evidence presented in Table III, p. 24 shows that:

1. The Physical Capacity Index No. 3 is the best measure of the kind of muscular factors that are necessary for maximum achievements in vigorous athletic activities. (The highly selective process of "making" a school team.)

2. Our findings show specifically that the new index corresponds with athletic achievement to the degree of .93. The old index (No. 2) with athletic achievement yields a correlation coefficient of .83 and the others correspondingly lower, i.e.,—Battery of athletic skills, .79; the Rogers Strength Test, .83; the Vertical Jump, .84; and the best of the individual tests, standing broad jump, .76.

Analysis of 1931 Data

From the 1928-1929 data it is obvious that the true picture is not shown because of the spurious influence of age. In order to meet this question fairly, it was decided to limit the data for 1930-1931 to one chronological age group. As before mentioned, the sixteen year old group was selected. Furthermore, the muscular strength measure was changed for a pure measure of muscular force. Other refinements from 1930-1931 experiments enabled us to raise the reliability of the vertical jump to .98.

The Physical Capacity Index No. 3 (Strength × Velocity) developed into the final index, namely, Physical Capacity Index No. 1 (Force Index multiplied by Velocity Index and the product divided by 100). Referring to Table III on 1931 sixteen year olds we find that:

1. Physical Capacity Index No. 1 correlated (bi-serial r) with athletic achievement yields a coefficient of .88 with a probable error of .03, while Physical Capacity Index No. 3 correlated with athletic achievement yields a coefficient of .85 with a probable error of .03 and the best battery of athletic skills (Modified Cozens Athletic Performance Index) correlated with athletic achievement yields a coefficient of .78.

2. The Basketball Index (see Chapter II) correlated with general athletic achievement yields a coefficient of only .42 with a probable error of .08. This evidence supports the theory that those highly skilled in one sport may not be expected to be skilled in a sport in which they lack adequate training.

TABLE V

PRODUCT-MOMENT CORRELATION COEFFICIENTS BETWEEN TWO VARIABLE COMBINATIONS AS INDICATED

(1931 Data—16 yr. olds—103 Cases)

Physical Capacity Index No. 1	*Product-Moment r's on 1929 Data* (220 Cases—Age Range—15.5.-20.0)
Weight ..... .62	
Height ..... .74	
Modified Cozens Athletic Index .. .83	
Basketball Index ..... .38	
McCloy Classification Index ..... .66	
Physical Capacity Index No. 2 (Strength plus Vertical Jump)	*Index No. 2* *Athletic Perfomance*
Modified Cozens Athletic Index .. .74	Vertical Jump ..... .74
	Rogers Strength Index ..... .70
	Physical Capacity Index No. 3 .. .80
	Age ..... .43

The statistical analysis was carried further by the use of the product-moment correlation technique. The findings are summarized in Tables II, III and V from which it was concluded that:

1. The Physical Capacity Index No. 1 (Force Index × Velocity Index) measures to a high degree the kind of muscular action (capacity) found in the performance of athletic skills as measured by the Modified Cozens Athletic Performance Index (Battery of seven individual athletic skills. See description in Chapter II). The coefficient of correlation was .83 on the data for 16 yr. olds.

2. The Physical Capacity Index No. 1 does *not* measure specific athletic skill to a high degree. The correlation between the Physical Capacity Index and basketball playing ability was only .38.

3. The factors of age, weight and height as expressed by the McCloy[8] Classification Index (20 age + 6 height + weight) are adequately accounted for in the Physical Capacity Index. The degree of correspondence was .66.

4. Physical Capacity Index No. 1 is a better index of athletic performance than Physical Capacity Index No. 3. The coefficients were .83 and .74 respectively.

5. Reducing the coefficients of correlation between athletic performance (Index No. 2) and strength (Rogers), and athletic performance and physical capacity (Index No. 3) to predictive indices[9] it is found that physical capacity as measured by Index No. 3 is a 29% (increase in predictive efficiency) better measure of athletic performance than strength (Rogers) (1929 data, ages 15.5 to 20 years, 220) and a 41% better measure of athletic achievement (16 year olds).

Since weight exerts an influence on force, it was decided to develop the Energy Index (Body Weight times the Vertical Jump). The reasoning was as follows:

(a) The amount of kinetic energy required to project a body upward a given distance equals ½ Wt. times the Velocity, where Wt. is body weight and the vertical jump is substituted for velocity.[10]

(b) The potential energy present in the body by virtue of its height, (distance) at the top of the jump, would equal the kinetic energy it took to project it upward to this position.[11]

[8] McCloy, C. H., The Measurement of Athletic Power, p. 137.
[9] Bailor, E. M., Content and Form in Tests of Intelligence, Ch. I.
[10] Millikan and Gale, op. cit., pp. 133-137.
[11] ibid., pp. 133-137.

(c) The Energy Index was computed by simply multiplying the individual's body weight by the height of the vertical jump.

(d) If the Index of Physical Capacity were all weight, the Energy Index would be as "good" a measure of the physical capacities of those that achieved high in athletics as the Physical Capacity Index. That this is not the case is evident from the findings summarized in Table III. The degree of correspondence between the Energy Index and athletic achievement is .70, while the same between the Physical Capacity Index and athletic achievement is .88.

Reliability

The reliability of the Physical Capacity Index was established from the data of 136 cases (age range 15.5-20 years). The reliability was acceptably high. The self r was .93.

Objectivity

Objectivity was partly established by the fact that trained student and faculty assistants assisted the investigator in the administration of the test, with consistent agreement of measurement.

Summary

1. The mechanical principle of power equals force times velocity was accepted by the investigator as the underlying principle in the measurement of physical capacity.

2. Statistical proof was furnished as to the validity of the Physical Capacity Index No. 1 (Force times Velocity) as a measure of the kind of muscular capacity present in athletic achievement and athletic performance.

3. The degree of correspondence between athletic achievement and physical capacity was established by the use of bi-serial r. Proof of validity was found in the coefficients of correlation as .93 (220 cases, ages 15.5-20 years); .88 (complete group of 16 year olds, 103 cases); and .86 (complete group of 17 year olds, 109 cases).

4. The Physical Capacity Index No. 1 was computed by multiplying the pounds of muscular force present in the muscles of the back, legs, trunk, arms and hands, by the muscular velocity of the large muscle groups used in a vertical jump (in inches) and dividing the product by 100.

5. The reliability of the Physical Capacity Index is high. The self r obtained was .93 (220 cases, ages 15.5 to 20 years.)

6. The Physical Capacity Index does not measure specific game skills. This conclusion was drawn from the fact that the correlation between basketball playing ability and physical capacity was low, only .38.

7. The physical factors of height and weight were accounted for in the Physical Capacity Index by showing the respective degrees of influence on athletic performance.

8. As proof that the Physical Capacity Index (muscular force times muscular velocity) was not all weight, a statistical comparison was made between the Energy Index and athletic achievement and the Physical Capacity Index and athletic achievement. The bi-serial r's obtained were respectively .70 and .88.

CHAPTER VI

CONCLUSIONS AND PRACTICAL APPLICATIONS

A. *Conclusions*

1. The Physical Capacity Index was proven to be a reliable and valid instrument for measuring the power of the large muscle groups.

2. The physical edueator will have at his disposal a tool for classifying pupils as to their physical capacities for performance in general physical education activities. It is not intended that the Physical Capacity Index should be used to elassify an individual as to his aptitude for any specific skill (as swimming or heavy apparatus work). The proof presented in this study was based on the closeness of correspondence between physical capacity, as measured by the Physical Capacity Index, and the kind of general physieal capacity found in an individual's performance and achievement in vigorous team games and sports. (The correlation coefficients found in Table III are .88 and .86 for sixteen and seventeen year old boys respectively. For an age range from fifteen years six months to twenty years, the correlation coefficients are, 1928 data .90; 1929 data .93.) McCall[1] contends that, "What a test really measures is known only by its correlations. The closeness of a test's correlation with what constitutes intelligence is a measure of its excellence as an intelligence test. This is the ultimate method of choosnig such a test. If this condition is satisfied, the examiner need look no further." The conclusion is obvious that the Physical Capacity Index is an excellent measure of the muscular potentialities required for physical achievement.

3. The application of the Physical Capacity Index to all ages from the Junior High School through the college is not an unjustifiable assumption. The data used in this study were comparable to the data on which Rogers[2] found that the application of the strength index could be extended to a wide age range of both sexes.

[1] How to Measure in Education, p. 213.

[2] Rogers, F. R., op. cit.

4. *Norms.* It is the investigator's feeling that the establishment of physical capacity norms for all ages is a precarious procedure. Norms of intellectual capacity (I.Q.'s) are established on the basis of random sampling from all sections of the country using many thousands of cases. Physical capacity norms computed from test data collected in Yonkers, N.Y., would only be useful in comparing boys from Yonkers, N.Y. Only where high school boys from other sections of the country are like high school boys of Yonkers in physical capacities would the norms be comparable. It is recommended that each school or school system establish their own norms of physical capacity and only on age levels where there are from two hundred to five hundred cases available.

5. The Physical Capacity Index was not devised to measure specific athletic skill and should not be used to predict athletic ability aside from the fact that athletic ability presupposes a high degree of physical capacity. (The closeness of correspondence is represented graphically in Chart III, Appendix.)

From the comparable growth curves indicated on Chart III the following interpretations seem appropriate:

(a) The curves show the characteristic plateaus at pubescence (11½ years to 13½ years).

(b) The neuromuscular functions reach maturity at approximately the eighteenth year. In other words maximum athletic skill may not be expected before the boy reaches the age of eighteen years.

(c) Beyond the eighteenth year the trends in terms of average neuromuscular functions tend to flatten out. Depending on training, muscular forces may be expected to increase in greater proportion than speed (velocity) of muscular reactions.

(d) Contrasted to the above deduction, below the eighteenth year, the function of muscular velocity is of more importance than muscular strength (force) in average athletic performance.

6. It is reasonable to believe that a rare individual could achieve 3,000 lbs. or more of force as measured by the Force Index and still have a low velocity index. Such an individual's Physical Capacity Index would be spuriously high even if his Velocity Index was low for his age and weight. However it is hoped that intelligence will be used in interpreting the score of this individual. It should be kept in mind that the ideal muscular capacity is one in which maximum power is used with the minimum expenditure of energy. More simply put, there should be a proper balance between mus-

cular force and muscular velocity, and for diagnostic purposes, care should be exercised in prescribing physical education activities for spurious cases.

7. From the following data taken from the findings as presented in Table III an evaluation of the best up-to-date classifying devices for physical activities may be formulated. On the basis of "goodness" as represented by the correlation coefficients the ranking would be as follows:

1. MacCurdy Physical Capacity Test ..... .88
2. Modified Cozens Athletic Test ..... .78
3. McCloy Athletic Power Test ..... .73
4. Rogers Strength Test ..... .72
5. Brace Motor Ability Test ..... .27

B. *Administration of the Physical Capacity Tests*

1. The instruments required for the administration of the Physical Capacity Index are the leg and back dynamometer, the hand dynamometer, a gymnasium horse and the vertical jump-meter. The aggregate cost of these instruments would be approximately $150.00 provided that the gymnasium horse and the traveling rings attachment for measuring arm pushing force were part of the regular standard gymnasium equipment.

2. The tests using one dynamometer should be given in two parts; on the first day, the vertical jump, force of legs, force of back and force of grips should be given; on the second day, the vertical jump should be repeated to have a check on the reliability of measurement, and the arm pulling and arm pushing tests should be given.

3. It is desirable that the tests be given during the first two weeks of the school year. The first week should be spent in training student and faculty assistants as examiners. The investigator found that high objectivity could be maintained by using students and faculty assistants in administrating the force of grips, the vertical jump, force of back, arm pulling force and arm pushing force. Objectivity of the leg force measurement was most difficult. However, experience and careful study of the instructions should enable any physical educator with intelligence to gain proficiency in giving this test.

4. Data cards similar to the sample below should be made out from the school registration cards to assure correct ages. The heights

and weights, although not an integral part of the tests, can be taken on the second day or at the leisure of students and instructors.

5. The computation of the Physical Capacity Index can be made by two student assistants during the administration of the test, one tabulating and the other checking results.

6. The data cards made out for each individual should be in files, in the testing room, in alphabetical order.

7. The motivation of the attainment of high scores should be emphasized. A scorer for each testing period is recommended to keep a cumulative record of the test results of two competing groups.

8. Testing time—75 subjects per class period with one set of instruments.

DATA CARD

Name *Jones, Henry*

Date	2/5/31			
Grade	10			
Age	16–6			
Weight	150			
Height	68			
V. Jump 1.	18.5			
V. Jump 2.	18.0			
Leg Force	600			
Back Force	300			
Grip Rt.	110			
Grip Lt.	100			
Arm Pull	250			
Arm Push	200			
Total Force	1560			
Best V. J.	18.5			
Phys. Cap. I. (T.F. x V.J.)				
(100)	288			

Note: Athletic records and other measurements may be placed on back of card. The figure 288 at the bottom of the card is this individual's Physical Capacity Index obtained by multiplying Total Force by Best Vertical Jump and dividing this result by 100.

C. *Test Booklet: The MacCurdy Physical Capacity Test*

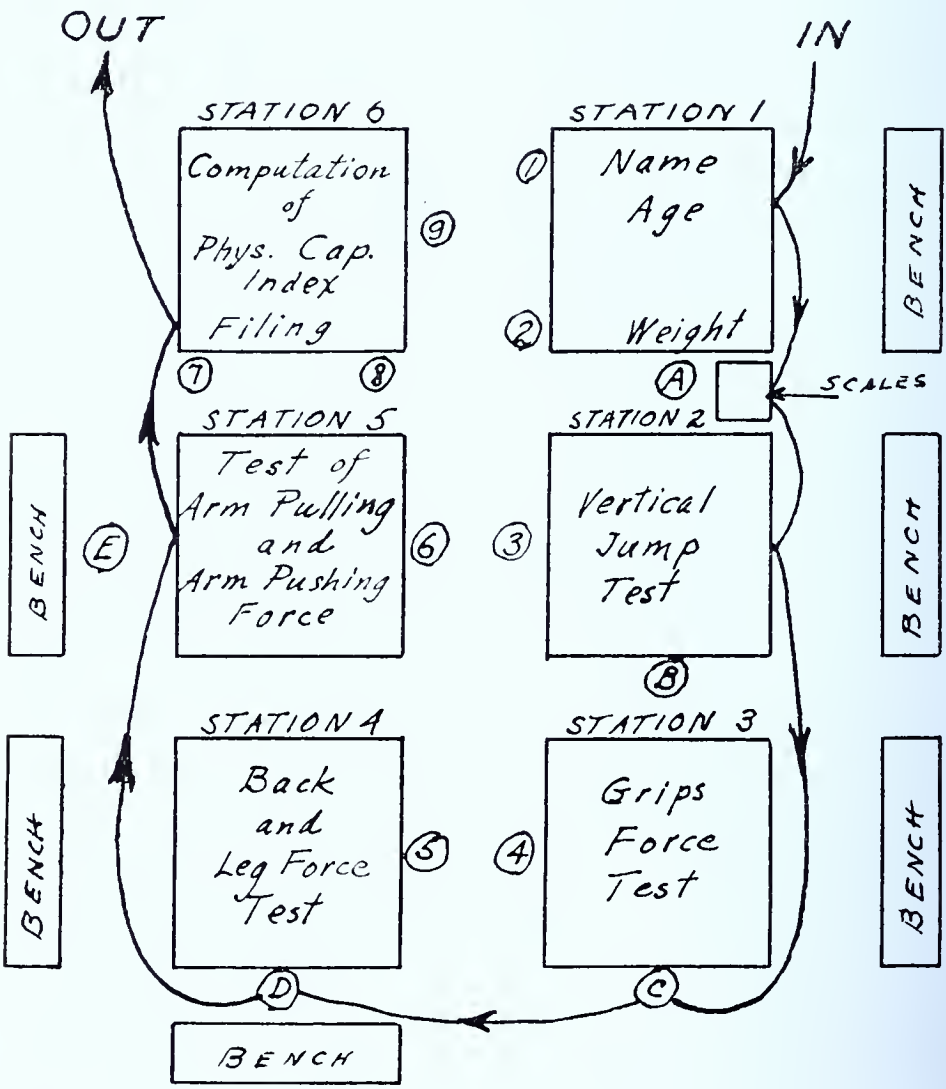
In order to facilitate the administration of the test, the following directions are presented for the reader who may wish to use the test.

General Directions

1. Data cards similar to the sample shown in the appendix should be prepared, one or more for each subject, to allow for replacements.

2. All subjects will be dressed in regulation gymnasium clothing.

ADMINISTRATIVE SET-UP FOR THE PHYSICAL CAPACITY TEST



NOTE:

Numbers in circles represent recorders. Letters in circles represent examiners.

3. A preliminary check-up on the physical disabilities (recent operations, fractures, sprains, serious illness, etc.) is advisable. All subjects will be cautioned, as they enter the examining room that they should *not* take the test unless physically fit. Those excused may be tested on a later date.

4. The testing instruments should be set up according to the plan presented in the diagram. All instruments should be tested for accuracy according to the directions accompanying each instrument (vertical jump-meter, leg and back dynamometer, scales and hand dynamometer) (standard instruments manufactured by the Narragansett Machine Co., Providence, R.I.)

5. Two days will be required to train the examining staff in their duties. During these periods, in order to secure more uniform results, it is advisable to present the vertical jump as a class exercise. Two five-minute practice periods will be sufficient to give every individual a mastery of the coordinations necessary for the best results.

Specific Directions

The stations will be staffed as follows: (See Diagram, p. 44.)

Station No. 1—at entrance to testing room (large enough to assure ample light, fresh air and seating arrangements for 100 subjects per hour).

No. 1 Recorder takes name of subject and age to nearest month. The subject's record card is passed to Recorder No. 2 who records weight to the nearest pound as observed by Examiner A.

Station No. 2—Recorder No. 3 records the best of the five vertical jumps (in inches) as observed by Examiner B, who adjusts the head strap of the vertical jump-meter tightly under the chin of subject and places subject in the erect standing position with feet in foot-square chalked or painted on the floor, so that the cord from top of head to lever arm is in a vertical position. (The lever arm should be adjusted so that the minimum height in the horizontal position is not less than 10 feet from floor. The tension on the springs should be such that the lever arm will fly up without any jerk on the cord.) The zero mark is made on the recording paper with the subject standing in his natural standing position.

Specific instructions to the subject are as follow:

1. Squat down until your upper leg makes a right angle with your lower leg, arms extended downward and backward.

2. From this position you will jump straight up as high as you can, extending the legs and throwing the arms vigorously upward.

3. Make your arms help you by pulling them down vigorously to a thrust position on your chest, as you straighten the neck, back and legs from the top of your head to the points of your toes.

4. You will do better if you hold the chin down and use your arms more.

(Examiner demonstrates)

Each subject is allowed five jumps and must pause in a fixed position at the bottom of each jump. This is regulated by the examiner commanding, "Ready, now give us your best—JUMP!" The Examiner reads off the best jump (to the nearest ¼ inch) to the recorder after rechecking zero reading. (If a difference occurs the subject must be re-tested.)

Alternate Method of Measuring Vertical Jump

If a vertical jump-meter is not obtainable, method (c) (described on page 9) may be considered the best alternate.

Station No. 3—Recorder No. 4 records the sum of the best of two grips with each hand as observed by Examiner C, who adjusts the hand dynamometer in the subject's hand so that one edge is placed well up against the second joints of the fingers and the other edge falls against the base of the thumb. Slight adjustment for comfort is allowable. The arm and hand must be held free from any contact as the subject grips to his maximum. The Examiner commands, "Bring your arm backward and upward. Now swing it vigorously forward and upward and grip with all your force." The Examiner takes first reading and prepares subject for second trial and commands, "Harder this time, give us a better one." The sum of the best left grip and best right grip is recorded as grip force (lbs.)

Station No. 4—Recorder No. 5 records the back force as observed by Examiner D, who adjusts the handle of the dynamometer so that the subject's finger tips are about four inches above handle when the subject is standing erect on dynamometer platform with feet close to attachment and toes even with front edge of platform. (If the dynamometer is placed on a low bench the examiner can make chain length adjustments and read records more readily.) The Examiner commands, "Take a firm hold of handle, one hand with

reverse grasp, keep knees straight. Now, heave, heave—ENOUGH.'' Record is observed to the nearest pound.

Without stepping off platform the subject's leg force is taken by examiner commanding, ''Bend your knees, allow handle to rest on upper thighs, grip handle with both hands close to chain.'' (If adjustment is properly made, hands should be well up in crotch.) ''Now straighten your back and arms. Steady, you are going to push your legs up against the handle with all your force. Ready—GO! Come on! More! MORE! ENOUGH!'' Read record to nearest pound. (Give two trials making slight adjustment on length of chain, one link either longer or shorter may put subject in a more advantageous position for maximum effort.)

Station No. 5—Recorder No. 6 records the arm-pulling force as observed by Examiner E who adjusts the height of gymnasium horse so that the top is even with the under surfaces of the subject's outstretched arms as he grasps the handle of the dynamometer. The length of the dynamometer chain should be so adjusted that the subject must stretch the arms to grasp the handle. The Examiner commands, ''Grasp the handle tightly, keep your feet on the floor and pull with all your force. More! MORE! Enough!'' The Examiner observes the dynamometer reading in pounds of force to the nearest pound. Arm pushing force is tested by placing subject with his back to the end of horse, the height of horse adjusted so that the top of horse is on a level with the top of subject's shoulders. The pushing attachment for the dynamometer is placed in position so that the straps go over each shoulder, with rings in subject's hands. The length of the dynamometer chain is adjusted so that, with the subject in the ''ready'' position, the arms are partially bent at an angle of about one hundred thirty-five degrees. The Examiner commands, ''Grasp the rings firmly, keep the feet together and push evenly with both arms. Ready! Push! More! MORE! Enough!'' The reading is observed to the nearest pound of force.

Station No. 5 (Girls)—Limited experimentation was conducted by the investigator on applying the MacCurdy Physical Capacity Test to girls and women. It was found that all the tests could be administered to girls by following the technique established for boys, with the exception of the arm pulling test. Plate VI shows the alternate method used.

Station No. 6—Recorder No. 7 takes subject's card and computes the Physical Capacity Index by adding the five tests of force to ob-

tain the Force Index. The Force Index is multiplied by the best vertical jump in inches and the result divided by 100. The final result is entered on the subject's card as the Physical Capacity Index.

Recorders No. 8 and No. 9 help check computations and file cards in file.

Summary

1. Examiners should read the directions carefully. Try each test yourself. Put a few subjects through for practice until you have mastered the technique. You should obtain consistent results on retesting the same subjects.

2. The Physical Capacity Index is a measure of power and can be used for:

(a) Equating teams for athletic competition.

(b) Classifying pupils in physical education activities according to individual needs.

(c) Determining whether or not the individual is working up to his capacity by comparing his achievement in physical activities to his physical capacity index.

(d) One phase of marking pupils in physical education activities.

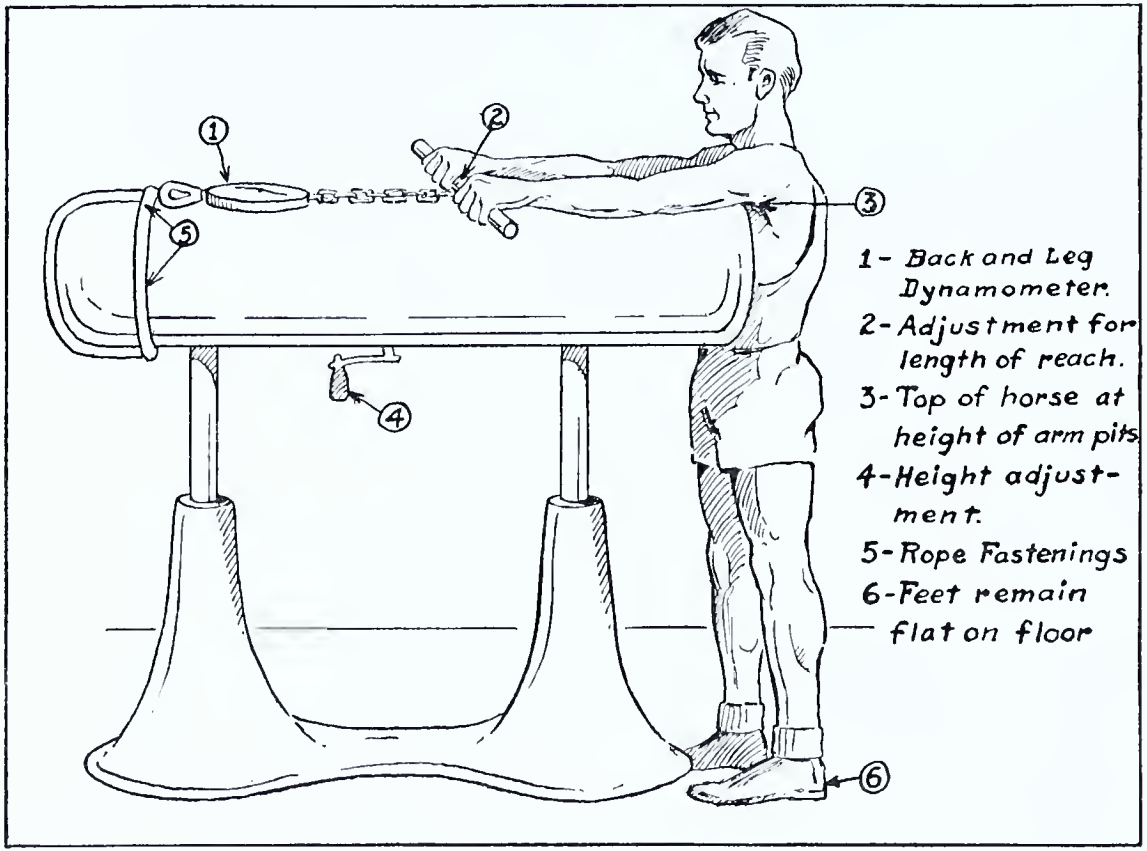
3. Where only one leg and back dynamometer is available, the physical capacity test may be given on two subsequent days:

(a) On the first day, the testing procedures at Stations No. 1, No. 2 and No. 5 are carried out.

(b) On the second day testing proceures at Stations No. 2 (repeated from first day), No. 3, No. 4 and No. 6 are carried out.

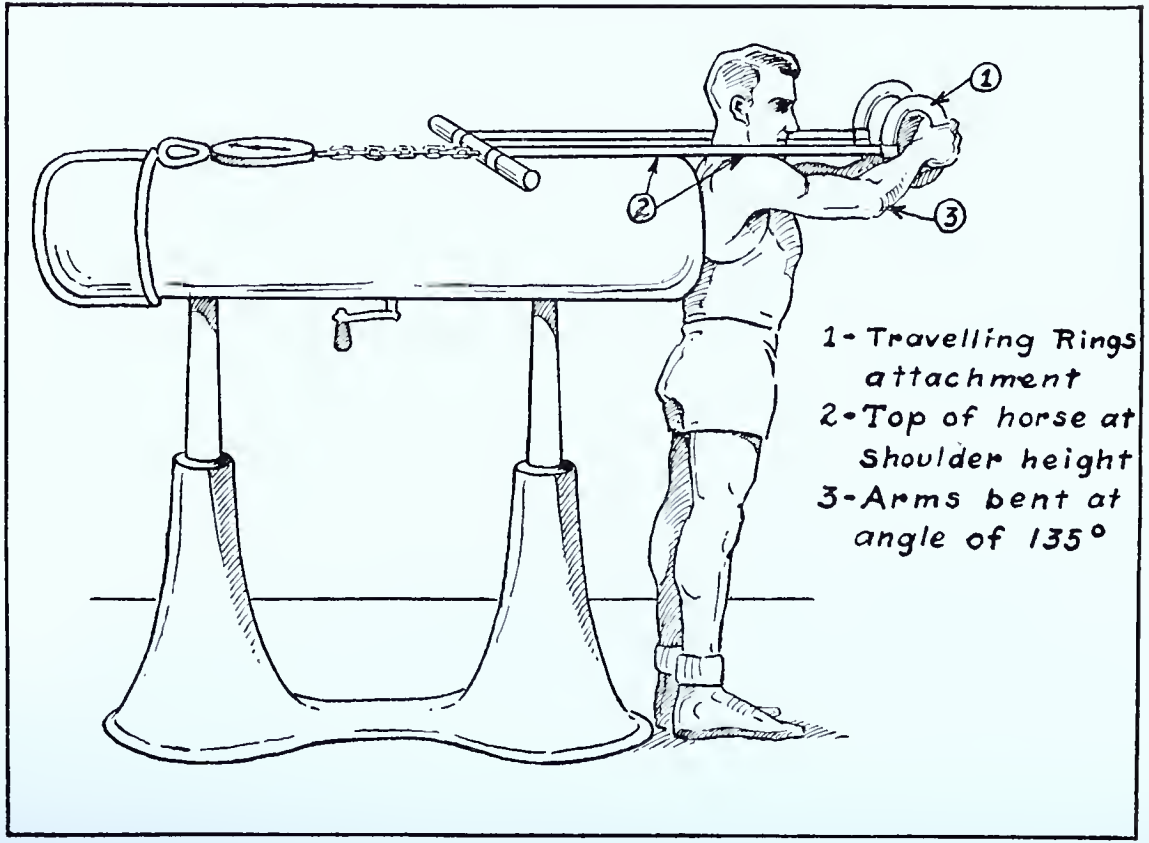
4. Table VI may be used as a guide for performance in the physical capacity test. The table shows the range of scores at the different age levels. Below the age thirteen years, six months, and above the age eighteen years the data are too few to be representative.

PLATE I



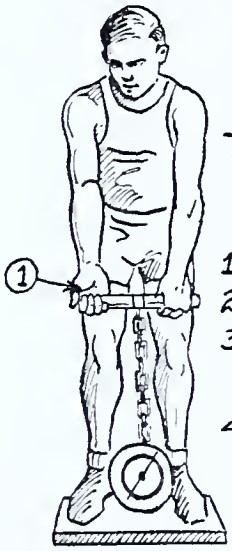
TESTING ARM-PULLING FORCE

PLATE II



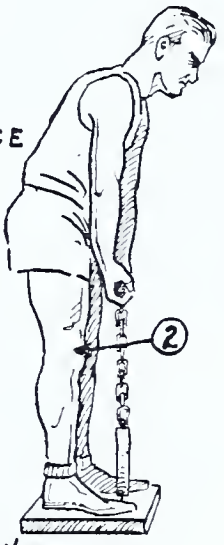
TESTING ARM-PUSHING FORCE

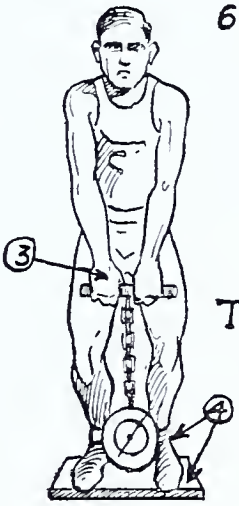
PLATE III



TESTING BACK FORCE

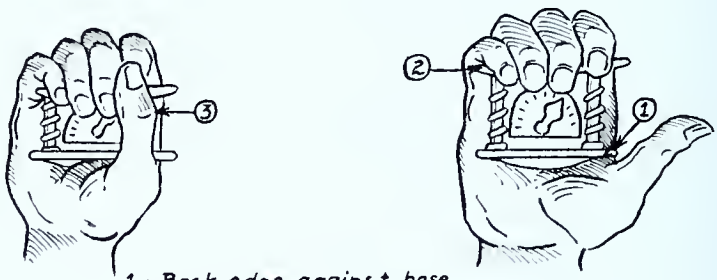
1- Reverse grip
2- Knees straight
3- Hands close to chain
4- Feet close to dynamometer toes even with front edge of board
5- Feet flat on foot board
6- Head up, back and arms straight





TESTING LEG FORCE

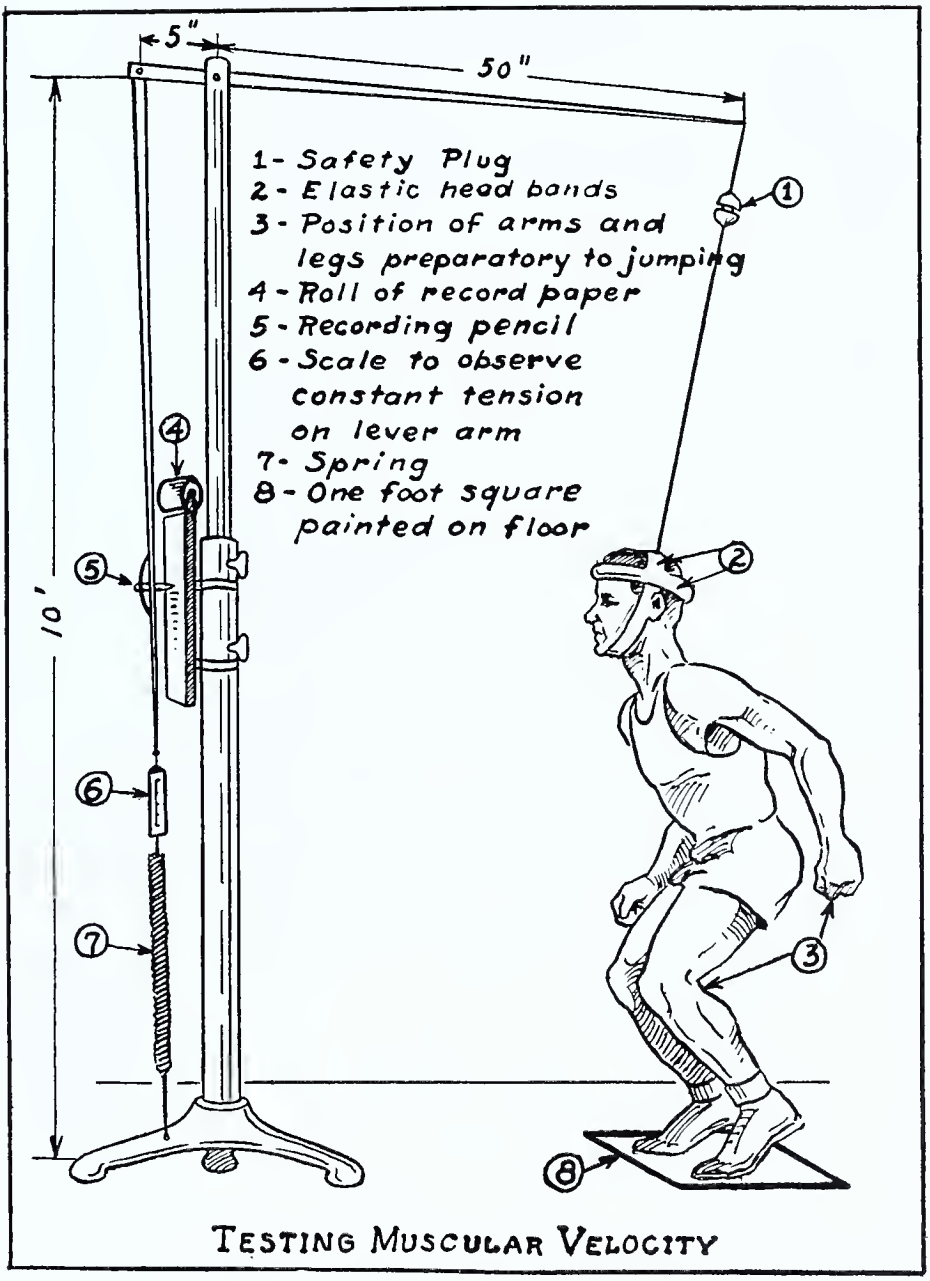
PLATE IV



1 - Back edge against base of thumb
2 - Front edge of dynamometer placed up against second joints of fingers
3 Position of fingers and thumb during grip

TESTING GRIP FORCE

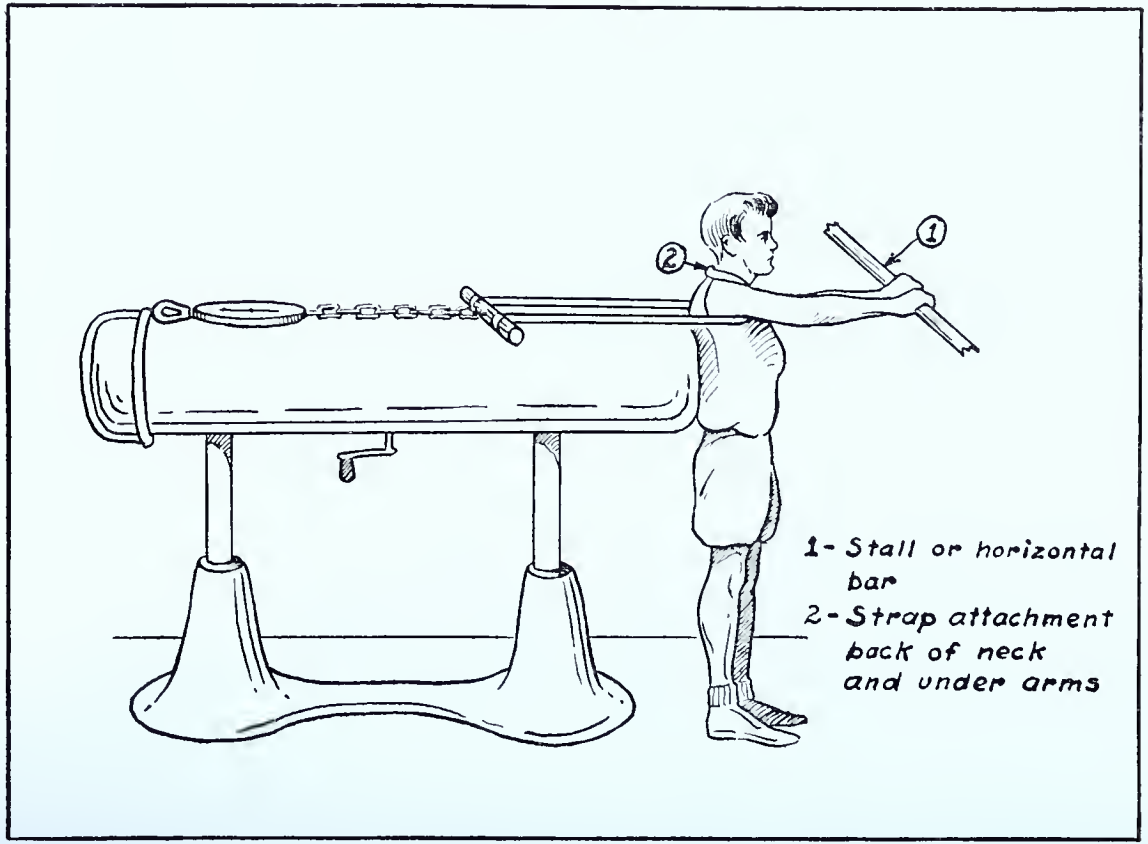
PLATE V


5"
50"
10'
1- Safety Plug
2- Elastic head bands
3- Position of arms and legs preparatory to jumping
4- Roll of record paper
5- Recording pencil
6- Scale to observe constant tension on lever arm
7- Spring
8- One foot square painted on floor

TESTING MUSCULAR VELOCITY

MACCURDY VERTICAL JUMP-METER

PLATE VI



TESTING ARM-PULLING FORCE OF GIRLS

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APPENDIX

A. *Statistical Procedures*

1. *Tabulation*—The number of cases was counted by two independent workers.

2. *Computation*—Bi-serial r's[1] were computed from the formula: (The condition of normality in the dichotomous series, on which this formula is based, was satisfied in these data.)

$$r_{(\text{bis})} = \frac{(M_1 - M_2)\, x(pq)}{\sigma_{(\text{dis})}\, x(z)}$$

Product-Moment r's[2] were computed on the calculator using the formula: (The condition of rectilinearity was satisfied by the data on the same chronological age [16 years]. See Table of Correlation-ratios [Appendix].)

$$r = \frac{r = \dfrac{EXY}{N} - M_x M_y}{\sqrt{\dfrac{E(X)^2}{N} - M_x^2} \cdot \sqrt{\dfrac{E(Y)}{N} - M_y^2}}$$

Where scattergrams were necessary to enable the study of individual cases product-moment r's were computed with the use of the log-log slide rule.

Probable errors of bi-serial r[3] on the most important measures were computed from the formula:

$$P.E. = \sigma_r(.6845 = \frac{\left(\dfrac{pq}{z} - r^2\right)}{\sqrt{N}}$$

Standard Difference Scores[4] were computed from the formula:

$$S.D.S. = \frac{M_x - M_y}{\sqrt{\dfrac{\sigma_x^2}{N_x} + \dfrac{\sigma_x^2}{N_y}}}$$

[1] Kelley, T. L. Statistical Methods, pp. 245-249.

[2] Holzinger, K. J. Statistical Methods for Students in Education, pp. 146-147.

[3] Kelley, T. L., op. cit., p. 249.

[4] Franzen, R. Physical Measures of Growth and Nutrition. p. 127.

CORRELATION COEFFICIENTS AND CORRELATION RATIOS*
FOR TESTS WITH THE PHYSICAL CAPACITY INDEX

	r	$(P.C.I.) \cdot (x)$	$(x) \cdot (P.C.I.)$
Athletic Performance	.83	.84	.86
Weight	.62	.63	.64
Height	.74	.74	.76

* Applying Blakeman's test $\left(\frac{\sqrt{N}}{.6745} \times \frac{\sqrt{N^2 - r^2}}{2}\right)$ no computation result was greater than 2.5.

Reliability coefficients in the main were computed from data where there were two applications of a given test.

B. *Supplementary Data*

1. Chart III was developed by equating the variabilities of the four measures and plotting the means for each half year age group.

2. Table VI is presented to show age distributions of the Physical Capacity Index.

3. Table VII shows a typical computation sheet for the computation of S. Diff. Scores and bi-serial r correlation coefficients.

TABLE VI

AGE DISTRIBUTIONS FOR THE PHYSICAL CAPACITY INDEX

Power Index	*Age* 0 13	6 13	0 14	6 14	0 15	6 15	0 16	6 16	0 17	6 17	0 18	6 18	0 19	6 19	0 20	6 20
580									1		1		1			
550									1		1		0			
520								1	0	2	1	3	0	2		
490							1	1	3	2	3	0	0	2		
460							0	1	5	2	3	2	0	0		
430						3	3	3	3	5	5	0	1	0		1
400					1	3	6	11	9	12	2	3	1	0	1	
370			1	1	4	6	4	13	10	7	13	6	2	1		
340			0	2	4	9	11	16	16	18	10	3	3	1	1	
310			1	3	9	11	21	17	16	11	7	5	1	2		
280			4	6	13	25	25	20	18	8	10	5	1			
250		1	4	13	18	38	22	28	13	7	8	4	1			
220		1	8	18	21	21	31	26	8	11	6	1	2			
190	4	4	11	21	21	23	13	11	8	3	5	0	0			
160	3	4	23	13	16	21	8	9	3	1	1	1	0			
130	6	11	17	21	11	11	11	6	2		0		0			
100	8	14	15	20	10	7	4	2	1		0		1			
70	8	6	6	2	8	2	1				1					
40		2	3													
N	29	43	93	120	136	180	161	165	117	89	77	33	14	8	2	1

Grand Total = 1267

TABLE VII

COMPUTATION SHEET

Bi-serial "r" / Standard Diff. Score — Leg Lift vs. Athletic Achievement — (May) (1931)

Athletic Achievement

Leg Lift	*Athletes*				*Non-Athletes*				*Totals*			
	F	*D*	*FD*	FD^2	*F*	*D*	*FD*	FD^2	*F*	*D*	*FD*	FD^2
760	1	6	6	36					1	8	8	64
720	1	5	5	25	2	7	14	98	3	7	21	147
680	3	4	12	48	6	6	36	216	9	6	54	324
640	2	3	6	18	2	5	10	50	4	5	20	100
600	4	2	8	16	11	4	44	176	15	4	60	240
560	3	1	3	3	11	3	33	99	14	3	42	126
520	8		40		22	2	44	88	30	2	60	120
480	9	1	9	9	35	1	35	35	44	1	44	44
440	2	2	4	8	36	0	216		38		309	
400	4	3	12	36	32	1	32	32	36	1	36	36
360	1	4	4	16	23	2	46	92	24	2	48	96
320	2	5	10	50	22	3	66	198	24	3	72	216
280			39	265	11	4	44	176	11	4	44	176
240					4	5	20	100	4	5	20	100
200					2	6	12	72	2	6	12	72
160					2	7	14	98	2	7	14	98
120					1	8	8	64	1	8	8	64

$N = 40$ $\quad N = 222$ $\quad 242 \quad 1594$ $\quad N = 262 \quad 254 \quad 2023$

$C_1 = .025$ $\quad C_2 = .117$ $\quad C = .21$

$C^2_1 = .0006$ $\quad C_2^2 = .0137$ $\quad C^2 = .044$

$C_1 = 1.50$ $\quad C_2 = 7.02$ $\quad S.D. = \sqrt{\frac{2023}{262} - .04}$

$M_1 = 541.50$ $\quad M_2 = 452.98$ $\quad S.D. = 166.60$

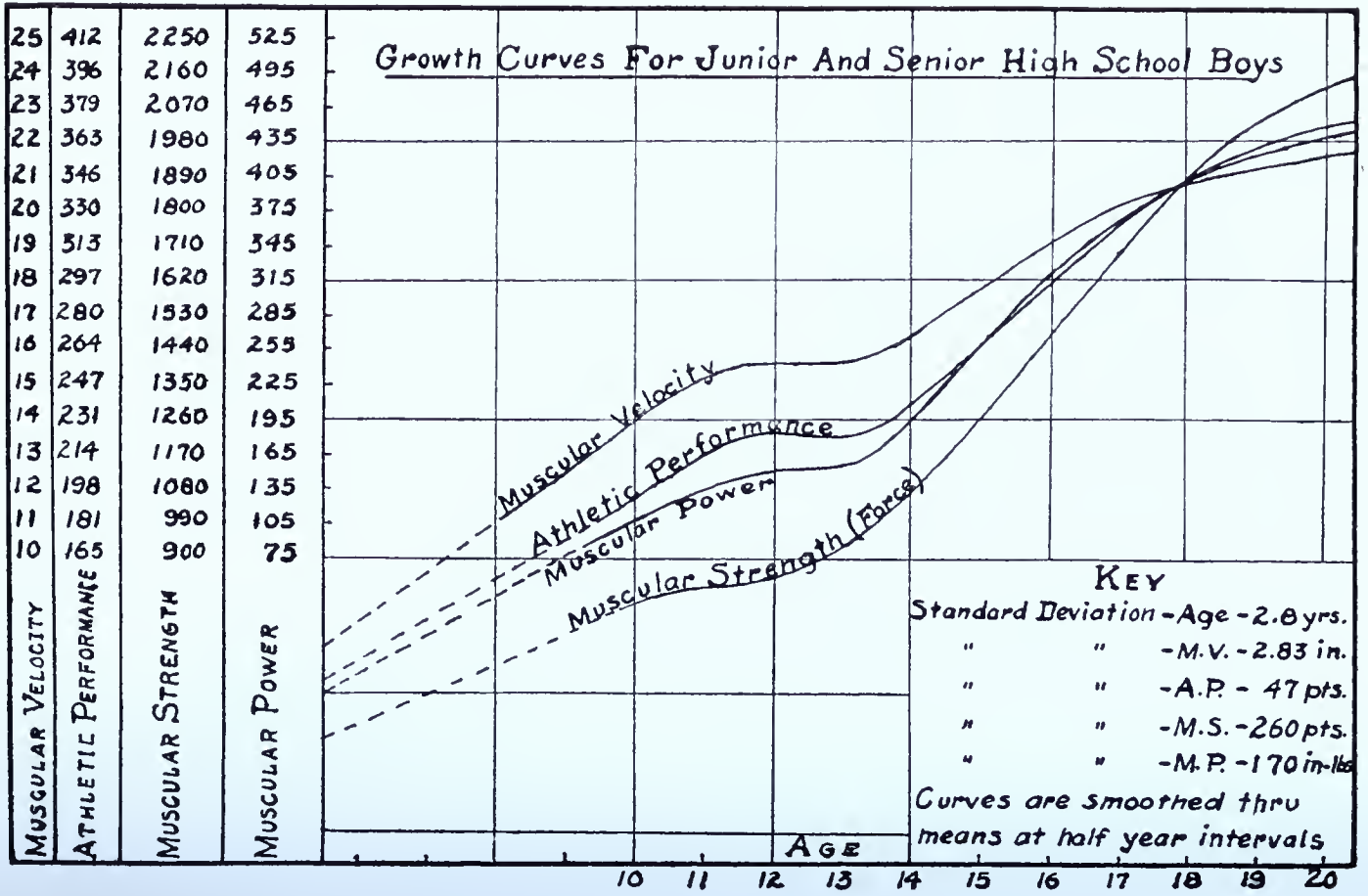
$S.D._1 = \sqrt{\frac{265}{40} - .0006} \times 60$ $\quad S.D._2 = \sqrt{\frac{1594}{222} - .01} \times 60$

$S.D._1 = 154.80$ $\quad S.D._2 = 160.80$ $\quad r_{(bis)} = \frac{88.52 \times .130}{166.6 \times .236}$

$S.D.S. = \sqrt{\frac{154.8^2}{40} + \frac{160.8^2}{222}}$ $\quad r_{(bis)} = .293$

$S.D.S. = 3.31$

CHART III


Growth Curves For Junior And Senior High School Boys
Muscular Velocity
Athletic Performance
Muscular Power
Muscular Strength (Force)
KEY
Standard Deviation - Age - 2.8 yrs.
" " - M.V. - 2.83 in.
" " - A.P. - 47 pts.
" " - M.S. - 260 pts.
" " - M.P. - 170 in-lbs
Curves are smoothed thru means at half year intervals
AGE
10 11 12 13 14 15 16 17 18 19 20
MUSCULAR VELOCITY
ATHLETIC PERFORMANCE
MUSCULAR STRENGTH
MUSCULAR POWER
25 412 2250 525
24 396 2160 495
23 379 2070 465
22 363 1980 435
21 346 1890 405
20 330 1800 375
19 313 1710 345
18 297 1620 315
17 280 1530 285
16 264 1440 255
15 247 1350 225
14 231 1260 195
13 214 1170 165
12 198 1080 135
11 181 990 105
10 165 900 75

VITA

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